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USE OF CASE HISTORIES IN THE DEVELOPMENT OF STUDENT UNDERSTANDING OF SCIENCE AND SCIENTISTS.
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THE USE OF CASES DRAWN FROM THE HISTORY OF SCIENCE WAS EVALUATED AS AN INSTRUCTIONAL PROCEDURE USING 108 SECONDARY SCHOOL CLASSES IN BIOLOGY, CHEMISTRY, AND PHYSICS LOCATED IN WIDELY DISTRIBUTED GEOGRAPHICAL AREAS. THE PURPOSE OF THE STUDY WAS TO DETERMINE THE EFFECTIVENESS OF THE HISTORY OF SCIENCE CASES INSTRUCTION METHOD (HOSC) IN CHANGING STUDENT UNDERSTANDING OF SCIENTISTS AND THE ROLE OF SCIENCE AS A SOCIAL INSTITUTION. THE EXPERIMENTAL DESIGN WAS AN ANALYSIS OF VARIANCE WITH COVARIANCE ADJUSTMENT. BOTH MAIN EFFECTS AND INTERACTIONS WERE UTILIZED FROM WHICH THE INVESTIGATORS CONCLUDED THAT THE HOSC INSTRUCTION METHOD IS DEFINITELY EFFECTIVE IN INCREASING STUDENT UNDERSTANDING OF SCIENCE AND SCIENTISTS AND THAT THE SO-CALLED INTANGIBLE OBJECTIVES OF SCIENCE INSTRUCTION CAN BE MEASURED. (JK)

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USE OF CASE HISTORIES IN THE DEVELOPMENT OF STUDENT UNDERSTANDING OF SCIENCE AND SCIENTISTS

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Cooperative Research Project No. 896

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Preface

Through the years, a great volume of educational research in the areas of curriculum and methods has been produced. Yet, this research has not had the kind of significant impact upon educational practice which might be expected to result from such a vast activity. Of course, there are many reasons for this, but a few important ones lie at the heart of the matter.

Frist of all, research in these areas has tended to be too broad; broad in the sense that method A is compared with method B, where both methods are expected to teach *all* aspects of a subject, say, chemistry. Secondly, the teacher variable is either ignored or inadequately considered. A third shortcoming is that the methods being considered are not described fully enough to enable other teachers to perform in a similar fashion. A fourth shortcoming is that inappropriate tests are chosen as the criterion instruments in the experiments. It is fairly easy to take an available standardized test "off the shelf" and use it as the criterion instrument, but a test that happens to be available is often a poor choice or, at best, a poor compromise. Finally, reported experiments often do not fully explore the numerous problems associated with instructional or curricular innovations, yet give the impression that the experiment has answered the question of the research once and for all time. Such incomplete research does not tend to inspire the confidence needed to base educational practice on its findings.

In the study reported here, we have tried to minimize the above difficulties. The HOSC Instruction Method which is evaluated in this study, was designed to attain a specific sub-set of science objectives, objectives which science educators generally acknowledge as important. It is not presented as a panacea for all instructional and curricular problems in science education!

The teacher variable was experimentally controlled. The most relevant teacher attribute (in our opinion) was measured and experimentally controlled, and the classes of the one-hundred participating teachers were randomly assigned to the treatments.

The HOSC Instruction Method has been thoroughly described so that teachers can use this method without requiring special in-service preparation. Ample teacher handbooks were prepared for each HOSC Instruction Method unit.

A special test, called Test On Understanding Science, (TOUS), developed in cooperation with the Educational Testing Service, was used in this investigation. Thus, the criterion instrument was not some general achievement test in science, but a special test designed to measure certain specific objectives of science instruction. These were the same objectives used in designing the HOSC Instruction Method materials.

We do not view this experiment as the final proof of the effectiveness of the HOSC Instruction Method. The data provided by this research strongly suggests that the HOSC Instruction

Method is "on the right track," but they also suggest further refinements of method, materials, and evaluation instrument. The view that this type of research is a continuous process rather than a final solution must be more widely adopted. We need to build such quality control operations into all our development work in education.

The above points are not made with the intent of having this study viewed as a model approach, but rather in the hope that these efforts will not be dismissed as "another one of those educational experiments." We feel there is something here to consider for those science educators who are concerned about certain important objectives of science instruction --student understanding of science and scientists-- which are not now being adequately attained.

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We wish to express our thanks to the many persons who have assisted us in various phases of this study. The names of the participating teachers, regional advisers, test administrators, and others who have contributed are given in Appendix C. Here, we wish to give a special acknowledgement to Professor Fletcher G. Watson of Harvard University. Not only did he serve as the Consultant for this study, but for many years Professor Watson has given us his friendly, patient, and incisive counsel in the development of the materials which made the study possible.

L. E. K.
W. W. C.

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Chapter I. Background of the Study.

The technological civilization, which dominates our world today, has been made possible largely through application of the fruits of scientific activity. There is every reason to believe that science, through its applications and its orientation, will have an increasing impact on our national and world society in the future, that science will play an even larger role in our lives than it does today. But, what is science? What understanding do high school students, the citizens of tomorrow, have of science and scientists?

For many years, as early as the 1930s, science educators have recognized the attainment of realistic understandings about science and scientists as desirable outcomes of secondary school science instruction. Such understandings have been frequently referred to as "*appreciations*" or "*intangibles*" and include understanding by students of science as an institution, of scientists as people, of the processes of science, and of the aims of science. In recent years, these understandings have come into greater prominence as important objectives for science instruction. For example, in the 59th Yearbook of the National Society for the Study of Education, we find in the summary of objectives:

> "...A student should learn something about the character of scientific knowledge, how it has developed, and how it is used. He must see that knowledge has a certain dynamic quality and that it is quite likely to shift in meaning and status with time. . . .

> " Young people need to understand the dependence of our society upon scientific and technological achievement and to realize that science is a basic part of modern living. ... A student should understand the relation of basic research to applied research, and the interplay of technological innovations and human affairs. ...
>
> "A student with a liberal education in science should be able to appreciate:
>
> 1. The importance of science for understanding the modern world.
> 2. The methods and procedures of science for their value in discovering new knowledge and extending the meaning of previously developed ideas.
> 3. The men who add to the storehouse of knowledge. ...
>
> " To understand the scientist is also to understand some of his attitudes, such as the desire to know and discover, a curiosity about the world, the excitement of discovery, and the desire to be creative.
>
> "...Inevitably the details of scientific investigation are seldom the same for any two problems. What is done is highly flexible and quite personal. Incentive, intuition, the play of imagination, fertility of ideas, and creativeness in testing hypotheses are important parts of the process. "[1]

These statements are typical of the ideas concerning the objectives of science instruction which appear in the writings of thoughtful educators, science teachers, and scientists. Yet, at the same time, the findings of several nationwide surveys and studies[2] indicate that high school students' understanding of the scientific enterprise and of scientists are quite inadequate in reference to the present and future national and world situation. These findings are particularly disturbing because they show that many students' understanding of science and scientists is not only inadequate but is frequently a gross distortion of what actually exists. One implication of these findings is clear: although most high school students necessarily take one or more science courses, they have not attained a realistic understanding of science and scientists as a result of their exposure to science instruction.

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[1] Rethinking Science Education; Fifty-ninth Yearbook of the National Society for the Study of Education, Part I. (Chicago: NSSE, 1960). Pages 24-36.

[2] For example, see Margaret Mead and Rhoda Metraux, "Image of the Scientist among High-School Students," Science, 126: 384-390, (1947); High School Students Look at Science, Report of Poll No. 50 of the Purdue Opinion Panel, (Lafayette, Ind.: Division of Educational Reference, Purdue University, November 1957); and Hugh Allen, Jr., Attitudes of Certain High School Seniors toward Science and Scientific Careers, (New York: Scientific Manpower Project, Teachers College, Columbia University, 1959).

Truly, this is a paradoxical situation, for the attainment of a realistic understanding of science and scientists has been an avowed objective of science instruction for many years. We suggest that the principal reason behind this paradox is that, although these objectives have often been stated, very few instructional procedures specifically designed for their attainment have been proposed. It is unlikely that any objectives will be achieved if purposive efforts are not made to teach for them. Thus, if the broad objective of having high school students attain realistic understanding of science and scientists is worthwhile, and we urge that it is both worthwhile and essential in the contemporary situation, there must be instructional materials and methods that are directed toward the achievement of this purpose in high school science teaching.

One possible source to draw upon for materials that may be used in attaining objectives concening the understanding of science and scientists is the history of science. The story of the development of science in the past provides us with valuable insights about the procedures of science, the organization of science to carry out its aims, and the characteristics of scientists. Moreover, the insights gained from considering the science of the past are equally true for science in the present and will be true of science in the future.

The potential value of using materials drawn from the history of science to convey to students a deeper understanding of science and scientists has long been recognized by a small number of high school science teachers, particularly by teachers of chemistry.[1] A more significant movement toward the organized use of materials from the history of science became evident on certain college campuses in the restructuring of general education courses in science following World War II. The earliest general education science course that employed extensive organized materials drawn from the history of science was established at the University of Chicago in 1945.[2] During the same period, new general education science courses that made considerable use of materials drawn from the history of science were introduced at several other colleges, including Antioch, Colgate, Harvard, and Wesleyan (Conn.).[1] In each instance, a major objective of the new courses was to provide students with a more realistic understanding of science and scientists, although the manner in which the historical materials were employed was different in each institution. At Harvard, one way of utilizing materials drawn from the history of science resulted in the development of a series of specially-prepared case histories.[2]

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[1] For example, see Greta Oppe, "The Use of Chemical History in the High School," Journal of Chemical Education, 13: 412-414, (1936); and Bernard Jaffe, "The History of Chemistry and its Place in the Teaching of Chemistry," Journal of Chemical Education, 15: 383-389, (1938).

[2] Joseph J. Schwab, "The Three Year Program," in University of Chicago Faculty, The Idea and Practice of General Education, (Chicago: University of Chicago Press, 1950), Pages 179-186 and 193-197.

It was the use of case histories in teaching science to non-science majors at Harvard that stimulated the development of an analogous series of case histories for use in high school science teaching. In chapter II, we shall describe these History of Science Cases for High Schools and the instructional method in which they are employed. Here, we only state the major purpose of the new instructional method: to provide high school teachers with a means for attaining the objectives concerning students' understanding of science and scientists.

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[1] See Earl J. McGrath (editor), Science in General Education, (Dubuque, Iowa: Wm. C. Brown Co., 1948).

[2] See James B. Conant, On Understanding Science, (New Haven: Yale University Press, 1947). Eight case histories were originally published in separate booklets, and these were collected in James B. Conant (general editor), Harvard Case Histories in Experimental Science, two volumes, (Cambridge, Mass.: Harvard University Press, 1957).

From this statement of the purpose of the new instructional method, the primary problem of the present study is derived. Is this instructional method, using historical cases in high school science teaching, effective in increasing student understanding of science and scientists? The exploration of this question, under the conditions and vicissitudes of actual classrooms, is the problem of our study.

Chapter II. The HOSC Instruction Method

The HOSC Instruction Method consists of the use of History of Science Cases for High Schools and attendant materials in an effort to achieve the objectives of science teaching which were discussed in chapter I. In this chapter, we shall describe the Cases and other components of the HOSC Instruction Method.

A. HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

In 1956, work was begun on a series of preliminary Cases which utilized historical narrative to illustrate aspects of the processes of science and the characteristics of scientists, as well as to teach specific science subject matter. Classroom trials of the preliminary cases by a number of teachers and critical commentary from many students, educators, and scientists led to substantial revisions and improvements in the format and developmental presentation of the Cases and, in 1959-60, to the preparation of an experimental edition.[1]

The experimental edition includes eight different Cases, each designed to be used within existing courses in high school biology, chemistry, or physics. Each Case is presented in a separate booklet of 28 to 32 pages, size $8\frac{1}{2}$ x 11 inches, printed on both sides. The major section of each Case contains, on the right-hand (odd-numbered) pages, the historical narrative with extensive quotations from the original writings of the scientists concerned. Marginal notes and questions along the right-hand side of the page call the student's attention to pertinent points about science and scientists that are illustrated by the historical narrative and to items of science subject-matter. On the facing left-hand (even-numbered) pages, the marginal questions are repeated and amplified, and space is provided for the student to write his answers to the questions. The format of the historical narrative section of each Case is shown in the sample pages (in reduced size) given in Appendix A.

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[1] The History of Science Cases for High Schools were not prepared as a part of the study reported herein. The experimental edition was published by the Department of School Services and Publications, Wesleyan University, Middletown, Conn., (Copyright 1960, by Leo. E. Klopfer).

Preceding the historical narrative section of each Case are an introduction to the student, setting forth the purposes of studying the Case, and a list of the principal scientists who appear in the Case with their dates and places of birth and death. Following the historical narrative section are a group of suggested experiments and exercises directly pertinent to the Case, a list of the sources of quotations used in the Case, and a list of reading suggestions in books and articles where students may delve further into the historical background, personalities, and science subject-matter of the Case.

The titles and brief summaries of the stories from the history of science contained in the eight Cases of the experimental edition are given below. There are three Cases in the field of biology---

Case 1, THE SEXUALITY OF PLANTS, follows the development of the concept of sexuality in the angiosperms from ancient Babylonia, through its experimental confirmation by Camerarius in the 17th century and its adoption in the Linnaean System of Classification, and culminates with Sprengel's classic studies of insect pollination near the end of the 18th century.

Case 2, FROGS AND BATTERIES, deals with the famous controversy between Galvani and Volta concerning "animal electricity". Galvani's studies of muscular contraction in frog's legs led him to a theoretical explanation of this phenomenon based on "animal electricity", but Volta denied the existance of "animal electricity" in this situation and developed his own explanation of muscular contraction. Extending his investigations, Volta devised the first electric battery, thereby furnishing an important new tool for biological and other scientific research.

Case 9, THE CELLS OF LIFE, traces the formulation of the fundamental theory that cells are the basic unit of all life by Schleiden, the botanist, and Schwann, the zoologist. This Case points up the key role played by the microscope in the development of the theory and shows how Schleiden and Schwann's ideas were modified by later investigators.

Two of the Cases deal with chemistry---

Case 3, THE DISCOVERY OF BROMINE, recounts the simultaneous discovery of a new chemical element by Löwig and Balard about 1825. Balard's investigation is followed in some detail as he establishes the similarity of the new element, bromine, to chlorine and iodine. This discovery strengthened the idea of families of chemical elements, which later found expression in the Periodic Law.

Case 8, THE CHEMISTRY OF FIXED AIR, focuses on the remarkable work of Joseph Black and others on carbon dixide. Black's key researchs in the middle of the 18th century put an end to the ancient idea of air being considered an element and initiated the era of experimental pneumatic chemistry. The identification and study of various gases led, in turn, to the development of modern chemistry in the hands of Lavoisier.

Finally, there are three Cases in the field of physics---

Case 4, FRAUNHOFER LINES, is concerned with the early history of spectroscopy. Starting with Newton's classical study on breaking up sunlight by means of a prism, the story quickly jumps ahead a century and a half to the observations by Wollaston and, especially, Fraunhofer of the dark vertical lines crossing the solar spectrum. These Fraunhofer lines remained a mystery until 1839, when the joint investigations of Bunsen, the chemist, and Kirchhoff, the physicist, provided an explanation of their origin, and, at the same time, launched the science of spectroscopy.

Case 5, THE SPEED OF LIGHT, follows the attempts, over a 300-year period, to determine the value of this important constant. Astronomical observations were employed in the earliest determinations until apparatus capable of coping with light's great speed could be devised to carry out terrestrial experiments. The Case takes up in succession the methods tried by Galileo, Roemer, Bradley, Fizeau, Foucalt, and Michelson,

Case 6, AIR PRESSURE, combines the story of the overthrow of the ancient Aristotelian doctrine that nature abhors a vacuum in the 17th century with the application of hydrostatic principles to explain the phenomena associated with atmospheric pressure. The pioneer work of Torricelli with the barometer included the idea that the mercury column standing at a height of about 30 inches above the level of mercury in a dish was balanced by the weight of the "sea of air" pressing on the surface of the mercury. Using hydrostatic principles, Pascal refined and rigorously worked out this "sea of air" idea and established our modern concept of air pressure.

From the foregoing summaries, it is evident that the Cases in the experimental edition encompass a variety of topics and range over a number of periods in the history of science. Yet, the particular narratives selected for the Cases represent but a small fraction of the interesting and instructive stories that could be drawn from the literature of the science of the past. What criteria govern the selection of a particular incident or development in science for retelling in a Case? The following considerations, relating to the instructional value of a Case and the practical expediency of having a given Case accepted for classroom use, are the principal criteria for selection:

1. The narrative selected must be able to yield clear insights into several major points concerning the process of science, the nature of the scientific enterprise, and the characteristics of scientists.

2. The science topic of the narrative must be one that is generally included in existing high school courses in biology, chemistry, or physics.

3. Most of the experiments associated with the narrative must lend themselves to replication (or approximate replication) by high school students within the limited resources and facilities of typical school laboratories.[1]

---

[1] One of the Cases in the experimental edition falls short on this criterion. In Case 5, THE SPEED OF LIGHT, the original experiments cannot be replicated readily in the high school laboratory, and, in fact, this particular Case includes only one laboratory exercise. Instead, Case 5 contains problems, based on the original data, from which students calculate the speed of light.

Of these three criteria, the first is clearly the most important, for it is for the purpose of giving students insights about science and scientists that the History of Schience Cases for High Schools were prepared.

B. USE OF THE CASES IN THE HOSC INSTRUCTION METHOD

The Cases just described are the core of the teaching units utilizing the HOSC Instruction Method. The Cases themselves are perhaps the most unique feature of these units, whereas the other components of the HOSC Instruction Method incorporate techniques, materials, and practices which are already quite widely used in science teaching. These components and their application in the HOSC Instruction Method units will be discussed in this and the following section.

A commonly accepted practice in science education is that an instructional unit should be designed to achieve certain specified and rather well-defined goals or objectives. In stating these objectives for a given unit, it is not sufficient to cite only the type of general aims which were discussed in chapter I. Though these general aims always are kept in mind as planning proceeds, a statement of the specific objectives that the instruction of a unit will strive to achieve must also be formulated. Accordingly, as each of the HOSC Instruction Method units was developed, a group of specific objectives for that unit was set down to direct the work. It was found convenient to group the objectives for a unit into the following three categories:

(A) Information about science subject-matter and the narrative of the Case.

(B) Understanding of science concepts and principles.

(C) Understanding of ideas concerning science and scientists.

Evidently, since the several units deal with a variety of science topics and narratives, the specific objectives under categories A and B differ greatly from unit to unit. On the other hand, the objectives in category C are quite similar for all the HOSC Instruction Method units. In many instances, an identical statement of a specific objective under category C is included in several units; always, the objectives under this category concern a specific understanding about the processes of science, the scientific enterprise, or the characteristics of scientists. The similarities as well as the differences in the objectives under category C may be seen clearly in the following extracts from the statements of objectives for three HOSC Instruction Method units - - one unit in biology, one in chemistry, and one in physics.

Extract from

Objectives for the Unit: THE SEXUALITY OF PLANTS

C. After studying this unit, students should understand (see Note) the following ideas concerning science and scientists:

1. Nature and roles of "hypothesis" and "theory".
2. The personal convictions of the participating scientists as well as experimental evidence are involved in the establishment of a scientific theory.
3. There is a dynamic interaction between the ideas of scientists with observations and experiments in scientific work.
4. A chain of reasoning, which often involves many assumptions, connects a theory with hypotheses that can actually be tested by experiments and observations.
5. Science is different from applied science and technology.
6. Scientists are unique individuals possessing a wide range of personal characteristics and abilities.
7. Nature and functions of scientific societies.
8. Science is an international activity.
9. Free communication among scientists is the lifeblood of science. Scientists communicate with one another through journals, books, meetings, and personal correspondence.

Note:

By "understand" we mean that the students should be able to do more than simply parrot back the statement of a principle, concept, or idea. They should understand it well enough to make an application of the principle or to seek out an example of the idea in a novel situation, such as they might meet on the unit test for this Case.

10. Importance of new and improved instruments in scientific work.

11. Although scientific investigations were carried out cheifly by amateurs in the past, research at the frontiers of science is a full-time professional activity today.

12. Progress in science is, in part, dependent upon the existing state of technology and on other factors in the culture outside of science itself.

Extract from

Objectives for the Unit: THE CHEMISTRY OF FIXED AIR

C. After studying this unit, students should understand (see Note) the following ideas concerning science and scientists:

1. The physical world does not change, but our understanding of it changes as we describe it in different terms.

2. Nature of scientific concepts and their influence on descriptions.

3. A scientist's observations and interpretations are influenced by the concepts he holds and by his background.

4. New apparatus and new techniques are important in making possible new experiments and the exploration of new ideas.

5. Problems of definition and identification.

6. Scientists are unique individuals possessing a wide range of personal characteristics and abilities.

7. Science is an international activity.

8. Nature and functions of scientific societies.

9. Science is different from applied science or technology.

10. The general state of technology and of the culture outside of science often influence the development of science.

11. Free communication among scientists is the lifeblood of science. Scientists communicate with one another through meetings, jounals, books, and personal correspondence.

12. Interaction of ideas and experiments in scientific work -- need for imaginative individual to provide hypotheses and for planned experiments to test them.

13. New observations have a trigger effect: they shake up established concepts and lead to new hypotheses and new experiments.

14. Use of scientific theories to "explain" natural phenomena.

Extract from

Objectives for the Unit: AIR PRESSURE

C. After studying this unit, students should understand (see Note) the following ideas concerning science and scientists:

1. Meanings and functions of scientific hypotheses, principles, and theories, and their interconnections.

2. Science is different from applied science and technology.

3. There is a dynamic interaction between ideas and experiments, between thinking and doing, in scientific work

4. A chain of reasoning, which often involves many assumptions, connects a theory with hypotheses that can actually be tested by experiments and observations.
5. Factors involved in the establishment of a scientific theory or concept include experimental evidence, the personal convictions of the participating scientists, and the theory's usefulness.
6. Scientific explanations of natural phenomena are given in terms of accepted laws and principles.
7. Scientists are unique individuals possessing a wide range of personal characteristics and abilities.
8. Science is an international activity.
9. Nature and functions of scientific societies.
10. Progress in science is, in part, dependent upon the existing state of technology and on other factors outside science itself.
11. Free communication among scientists is the lifeblood of science. Scientists communicate with one another through journals, books, meetings, and personal correspondence.
12. New observations have a trigger effect: they shake up established concepts and lead to new hypotheses and new experiments.
13. New apparatus and new techniques are important in making possible new experiments and the exploration of new ideas.

We would like to call particular attention to the continuity of the objectives under category C which are illustrated above. It is this continuity of objectives for all the units, together with a consistency in the teaching materials designed to achieve these objectives, which unites the several units into a common, instructional method.

When a HOSC Instruction Method unit is used in the classroom, each student receives a copy of the Case booklet, in which he reads the story of the Case, takes notes, and answers the questions asked in the marginal commentary. The general approach of the HOSC Instruction Method is to set the Case in a framework of class discussions. In these discussions, the role of the teacher is to set the stage in terms of the period of history in which the Case takes place and to supply some of the background facts and ideas which the students may lack. Generally, the students are able to discover for themselves the ideas about science and scientists which the Case is seeking to convey by considering thoughtfully the marginal notes and questions. To encourage students to consider these matters, it is recommended that they be required to write out directly in the Case booklet their answers to the questions in the margins as homework assignments. The students' answers to the marginal questions may then serve as the bases for the class discussions. Some of the marginal comments also lend themselves to individual or group assignments of supplementary reports based on suitable reference books.

An essential compenent of each HOSC Instruction Method unit is the group of related Experiments and Exercises, which are found in each Case booklet following the narrative of the Case. Though they have been collected in one place because of the technical requirements of the printing format, the several Experiments and Exercises are actually intended to be worked out by the students at the appropriate points in their study of the unit. To this end, references to particular Exercises are given within the narrative of the Case as it progresses. These Experiments and Exercises are designed to provide for students with a variety of abilities and skills, and they include laboratory experiments or problems, discussion questions, reports, and projects. (Typical examples of Experiments and Exercises from several Cases are given in Appendix A.) In most instances, the laboratory exercises are replications or closely similar analogues of the original experiments cited in the historical narrative of the Case. The intent is for the students to work out as many of the Experiments and Exercises as possible, so that they may get a "feel" for the kinds of problems with which the scientists in the Case were wrestling. The Experiments and Exercises are also of importance in helping students obtain a grasp of the manipulative and conceptual difficulties invariably present in scientific discovery.

In summary, then, the major components involved in the use of the History of Science Cases for High Schools in the HOSC Instruction Method are: the specification of objectives, which provide an over-all unity among the units; the instructional setting of the units in a framework of class discussions; and the employment of closely-partinent student exercises within the units.

C. INSTRUCTIONAL AIDS AND EVALUATION

Three types of instructional aids are provided to facilitate the use of the HOSC Instruction Method units in the classroom. These instructional aids are the Teacher's Guides, the unit tests, and supplementary books, reprints, and samples of "hard stuff".[1] The eight Teacher's Guides,[2] one of each HOSC Instruction Method unit, each contain approximately 50 to 70 mimeographed pages, size $8\frac{1}{2}$ x 11 inches and typed single-spaced. Such a comprehensive Teacher's Guide is necessary to accompany each HOSC Instruction Method unit because, in general, teachers are not familiar with this instructional approach and have no opportunity to receive training in it. Thus, the Teacher's Guide must incorporate not only the "right" answers to question, as is frequently the case in such aids to teachers, but also rather detailed discussions dealing with procedures and background insights.

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[1] The term "hard stuff" is the most convenient rubric we know to designate concisely the variety of actual objects, materials, and devices that scientists handle and work with. We are indebted to Professor Fletcher G. Watson for this convenient term.

[2] The Teacher's Guides were not prepard as a part of the evaluative study reported herein. Developed as an adjunct to the History of Science Cases for High Schools, they were compiled by Leo. E. Klopfer with the assistance of a group of science teachers and writers, including Maurice Belanger, Elba O. Carrier, Abraham Flexer, Roberta Flexer, Allan Furber, Eugene C. Lee, James W. Miller, Bernard O'Donnell, and John J. Seiler.

Each Teacher's Guide consists of four inter-related parts. The four parts, with a brief summary of the contents of each, are:

Part I. Orientation and Organizational Matters.

Contains an introduction for the teacher on the purpose of the HOSC Instruction Method and general comments on its classroom use. Also included are a list of the instructional aids for the unit and a table of page references to standard high school textbooks where the science subject-matter of the unit is discussed.

Part II. Teaching the Case by the HOSC Instruction Method.

This part constitutes the major portion of each Teacher's Guide. It includes a statement of the objectives for the unit (see section B above), a suggested schedule for teaching the unit in ten class lessons, and questions for review at the end of the unit. However, the bulk of this part is devoted to rather detailed, page by page, commentaries on the questions asked in the Case booklet and specific suggestions on procedures, points to be emphasized, and teaching techniques.

Part III. Notes on the Experiments and Exercises.

Discusses the experiments and exercises of the unit and, where appropriate, suggests additional and alternative student activities or teacher demonstrations that may be performed.

Part IV. Supplementary Materials.

Contains one-page biographical sketches on each of the principal persons who figure in the story of the Case and notes on the 35mm film slides which accompany the unit.

The content and form of the Teacher's Guides will be more apparent if the reader will refer to the typical sample pages included in Appendix A.

The second type of instructional aid for the HOSC Instruction Method is concerned with evaluating student achievement in their study of the units. As with any instrument which seeks to assess achievement over a period of study, the eight unit tests that have been devised measure only selected portions of the material in each unit. Nevertheless, the more significant portions of the material were selected for coverage in the questions of the several unit tests. Questions were designed to test both for the science subject-matter (i.e., for the objectives under categories A. and B.) and for the ideas concerning science and scientists (i.e., for the objectives under category C.) developed in the unit, with approximately equal weight given to each. The types of questions employed may be seen in the sample unit tests reproduced in Appendix A.

The third type of instructional aid used with the HOSC Instruction Method units consists of a variety of items, including supplementary books, reprints, and samples of "hard stuff".

These items are assembled in a Teaching Kit, which accompanies each unit. Some of the items, e.g., books that discuss scientific methods, are the same in all the Teaching Kits, but most of the items, which pertain only to the topic of a particular Case, are unique to the corresponding Teaching Kit. The Teaching Kits do not contain those pieces of laboratory equipment and supplies which are ordinarily available in high school science laboratories.

The variety of supplementary materials included in the Teaching Kits is illustrated in the following lists of the contents of those which accompany two of the units.

CONTENTS OF THE TEACHING KIT.

Unit 2: "Frogs and Batteries"

Item No.	Description
X-111	NORDENSKIOLD, The History of Biology.
X-201	CONANT, On Understanding Science.
X-202	CALDER, Science in Our Lives.
X-211	GOLDSTEIN, How to Do an Experiment.
X-221	Reprints from scientific journals. (A packet of reprints with a descriptive sheet.)
X-222	Some scientific and technical meetings. (A lengthy list of meetings held between 15 August and 28 October 1960.)
2-1	Slide Set[1]
2-2	Unit Test (1 copy per student in the class)
2-3	DIBNER, Galvani - Volta.
2-4	Aluminum foil
2-5	Copper wire

(continued)

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[1] Sets of 35-mm color slides, showing portraits of scientists, pictures or diagrams of apparatus, pages of scientific journals, etc., were prepared to accompany each of the HOSC Instruction Method units. Due to technical and financial problems, these slide sets could not be distributed to the classes participating in the HOSC Instruction Project.

Item No.	Description
2-6	Iron wire
2-7	Iron sheet
2-8	Copper squares
2-9	Zinc squares

CONTENTS OF THE TEACHING KIT.

Unit 3: "The Discovery of Bromine"

Item No.	Description
X-121	PARTINGTON, A Short History of Chemistry.
X-122	DAVIS, The Chemical Elements.
X-201	CONANT, On Understanding Science.
X-202	CALDER, Science in Our Lives.
X-211	GOLDSTEIN, How to Do an Experiment.
X-221	Reprints from scientific journals.
X-222	Some scientific and technical meetings.
3-1	Slide Set
3-2	Unit Test (1 copy per student in the class)
3-3	SMITH, Bromine and Its Discoverers. (Reprint)
3-4	BALARD, Mémoire sur une Substance particulière contenue dans l'eau de la mer. (Reprint)
3-5	"Water from Kreuznach Spa"
3-6	Sample of *Fucus*

These, then, are the components and materials of the HOSC Instruction Method. In chapter III we shall describe the HOSC Instruction Project, a study designed to evaluate this instructional method in the classroom.

Chapter III. The HOSC Instruction Project

As pointed out in the previous chapters, the principal motivation for the development of the History of Science Cases for High Schools and the HOSC Instruction Method was to provide a viable means of conveying to students a better understanding of science and scientists. However, lofty hopes for a new instructional method are insufficient grounds for recommending its introduction into general practice, so that the problem remained of determining whether or not the use of the HOSC Instruction Method could achieve the stated objectives effectively. Would high school students who had studied under the HOSC Instruction Method attain a significantly better understanding of science and scientists than other high school students, under similar conditions, who had not?

The study to evaluate the HOSC Instruction Method was carried out in the schools during the academic year 1960-61, with preparatory work having been done in Spring, 1960. It will be referred to as the HOSC Instruction Project hereafter.

A. EXPERIMENTAL DESIGN

An accepted procedure for investigating the effectiveness of an instructional method is to measure the change in students' scores on an appropriate criterion instrument. If, in addition, we wish to compare the instructional method in question with any other instructional method, we must also measure the change in the criterion instrument scores of students in a control group that does not utilize the instructional method being investigated. This leads to an analysis of variance design.

The purpose of the main analyses of the HOSC Instruction Project was to determine if students who were in classes where the HOSC Instruction Method was used achieved greater gain in their scores on the criterion instrument, which measures understandings about science and scientists, than students in classes where this method was not used. In addition we believed that there might be differences in the effectiveness of the HOSC Instruction Method depending upon the type of science course (biology, chemistry, or physics) in which it was used. We also believed that there might be differences in effectiveness due to differences in the classroom teacher's understanding of science and scientists. These last two factors were introduced into the analysis of variance design by stratifying the sample along two additional dimensions. Furthermore, a student's final score on the criterion instrument is, in part, a function of his general scholastic aptitude and of his initial performance on the criterion instrument, regardless of the instructional method under which he studies. Thus, the design used for the main analyses was a three-way analysis of variance design with covariance adjustments for scholastic aptitude and initial achievement.

The main hypothesis, stated in the null form, tested in the HOSC Instruction Project was:

> There are no significant differences in understanding of science and scientists between students who have studied under the HOSC Instruction Method as part of their regular science class work and students who have not.

A second question which we investigated in the HOSC Instruction Project was whether or not the use of the HOSC Instruction Method affects student achievement in the usual content of a science course. This question is of considerable practical importance whenever the introduction of a new instructional method is contemplated. An answer to the question may be found by comparing the scores of students in the experimental group, which uses the HOSC Instruction Method, with the scores of students in the control group on standardized science tests in either biology, chemistry, or physics, as appropriate to the course. The scores on such tests are usually correlated with general scholastic aptitude. Thus, a suitable experimental design is a one-way analysis of variance with covariance adjustment. Separate analyses are required for the biology, chemistry, and physics classes.

The hypothesis, stated in the null form, on the question of science content achievement was:

> There are no significant differences in achievement in the usual science content of the course between students who have studied under the HOSC Instruction

Method as part of their regular science class work and students who have not.

In the remainder of this chapter we shall describe and discuss the means employed to test the above hypotheses in the HOSC Instruction Project. Findings will be presented in chapter IV.

B. ORGANIZATION OF THE HOSC INSTRUCTION PROJECT

The first phase of the organization of the HOSC Instruction Project was the solicitation of teachers and classes to participate in the Project. This was done during the latter half of April and the month of May 1960 through the following three mechanisms:

(1) Personal letters inviting their participation in the Project were sent to 158 science teachers who had previously expressed an interest in the History of Science Cases for High Schools and the HOSC Instruction Method. The teachers were informed of the intent and operation of the Project and were asked to designate one "participating class", with the understanding that this class would be randomly assigned either to the experimental or to the control group. They were also requested to obtain the approval of the local school administration for their participation in the Project. In addition to two information sheets, a reply form

(see Form fe/1 in Appendix B) and a stamped return envelope were enclosed with the letters. From this mailing, 120 replies were received, or a return of 76%. The replies yielded 53 participating classes, widely-distributed geographically.

(2) A group of approximately 35 science teachers attending the Academic Year Institute at Harvard was solicitated by the investigators for participation. Four teachers from this group offered to participate in the Project.

(3) Letters were sent to ten professors of science education in various parts of the country with the request to nominate teachers in their respective regions for participation in the Project. The qualification suggested for a nomineee was that the teacher be concerned with conveying realistic understandings about science and scientists to his students. Seven lists of names of teachers of biology, chemistry, and physics were received in response to our requests. Personal letters were sent to 97 teachers on the lists to inform them of the Project and invite them to participate. The letters and information sent were essentially the same as in (1) above, and the same reply form and stamped return envelope were enclosed. From this mailing, a return of 75% was obtained, yielding an additional 64 participating classes.

Thus, as a result of these efforts, a total of 121 classes was initially obtained for participation in the HOSC Instruction Project. The classes were located in schools in 26 states. Fifteen classes were in private schools and 106 classes were in public schools.

The large number and wide geographical distribution of the participating classes presented a major organizational problem for the pre-test and post-test administrations of the Project. In order to assure a good experimental study, it was imperative to have disinterested test administrators from outside the schools in which the participating classes were located, especially for the pre-testing. The chief reasons for this were to attain greater uniformity in the testing, to avoid any possible influence on the testing if it were done by someone in the participating class's school, and to eliminate the risk of the participating teachers scrutinizing the criterion instrument at the pre-test administrations. Outside test administrator for each participating class were obtained in two ways.

First, the professors of science education, whom we had contacted to obtain the names of potential participating teachers, were asked to serve as Regional Advisers and to set up Regional Centers for the HOSC Instruction Project at their respective college or university. At these Regional Centers and through the efforts of the Regional Advisers, the testing of the participating classes located in a particular area could be organized and co-ordinated. The Regional Advisers were asked to recruit some of their advanced students or staff members, who would be paid a modest honorarium plus travel expenses, to administer the tests. Eight professors agreed to cooperate with the Project in the manner outlined, and the following Regional Centers were designated:

Code	Regional Center	Regional Adviser
NJ	Montclair State College	Prof. Hugh Allen, Jr.
FS	Florida State University	Prof. J. Stanley Marshall
OS	Ohio State University	Prof. John S. Richardson
MS	Michigan State University	Prof. Frederick B. Dutton
UM	University of Minnesota	Prof. Clarence H. Boeck
UN	University of Nebraska	Prof. James A. Rutledge
SF	San Francisco State College	Prof. Charles E. Burelson and Prof. Robert Stollberg
HU	Harvard University	(Project staff)

With these arrangements, the testing was covered for a majority of the participating classes, but it was still necessary to obtain test administrators for a considerable number of classes located outside the convenient reach of the Regional Centers. For this purpose, personal letters were sent to 32 professors of education or administrative officers in colleges and universities in the vicinity of a participating class with the request to co-operate with the Project by serving as a test administrator or, alternatively, by designating a responsible person to do so. This procedure proved to be highly successful, and, with some additional correspondence and a few telephone calls, the necessary test administrators were obtained. As in the Regional Centers, each test administrator received a modest honorarium and was reimbursed for his travel expenses.

Testing materials were shipped to the Regional Centers, where they were distributed to the test administrators located there, or were mailed directly to those test administrators not located at Regional Centers. In addition to a supply of test booklets, answer sheets, and electrographic pencils, each test administrator received detailed instructions on procedure (for example, see Form i/6 in Appendix B), necessary forms, and directions for giving the tests. A report of each test administration (for example,see Form fe/4 in Appendix B) was required to be submitted with each class set of answer sheets when it was mailed back to Cambridge. In this way, information about the conditions prevailing when the tests were given could be obtained.

While the solicitation of participating classes, organization of the Regional Centers, and securing of test administrators were under way, other preparatory and organizational activities were also pursued during the summer of 1960. Books and supplies for the Teaching Kits were selected, ordered, and assembled. Questionnaires, forms, and information materials were prepared and duplicated, and numerous organizational details were attended to in order to put the HOSC Instruction Project into operation.

C. OPERATION OF THE PROJECT

1. Assignment of Experimental and Control Classes

Of the 121 participating classes whose teachers had agreed to join in the Project, 116 were normal high school classes in first year biology (45 classes), chemistry (42 classes), or physics (29 classes). For each science subject category, the participating classes were randomly assigned either to the experimental group or to the control group. The resulting breakdown of the sample was as follows:

Biology: 23 experimental classes; 22 control classes
Chemistry: 21 experimental classes; 21 control classes
Physics: 15 experimental classes; 14 control classes

The remaining five participating classes presented special curricular or organizational situations, in which we felt it would be of interest to obtain an indication of the usefulness of the HOSC Instruction Method, even though it would not be possible to obtain control data. These five classes included:

3 classes studying a type of integrated science course
    (biology-chemistry: 1 class; chemistry-physics: 2 classes)
2 classes studying under a team-teaching organization
    (biology: 1 class; chemistry: 1 class)

These classes were designated as "Experimental Group B". Data collected from this group were kept separate from those obtained on the experimental and control classes in the principal sample.

On 21 June 1960, a letter was sent to each participating teacher informing him of the assignment of his class either to the experimental group or to the control group. The responsibilities of a teacher of an experimental class or of a control class, as applicable, were again outlined in this letter.

2. Description of the Sample

Changes in teachers' situations during the summer months resulted in a slight contraction of the original sample from 116 classes to 108 classes.[1] Thus, when active operation of the Project began in September 1960 the sample was constituted as shown in Table 3.1 .

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[1] The eight classes dropping out of the sample were distributed as follows:

Biology, experimental:	4 classes
Chemistry, experimental:	2 classes
Chemistry, control:	1 class
Physics, control:	1 class

Seven teachers dropped out for various personal reasons; one teacher was reassigned to a class in Physical Science, which was continued in the Project in "Experimental Group B". Of the eight classes dropped, six were in public schools and two were in private schools.

Table 3.1

Distribution of Participating Classes by Subject
September 1968

Subject	Experimental Group	Control Group	Total
Biology	19	22	41
Chemistry	19	20	39
Physics	15	13	28
Total Sample	53	55	108
"Experimental Group B"	6		114

(A roster of the participating classes and teachers is given in Appendix C.)

From information furnished by the participating teachers, several checks were run to compare the experimental and control groups. Chi-square tests were applied to detect any significant differences. The following variables were checked:

Number of students enrolled in the participating class	See Table 3.2
Selection of students for the participating class	See Table 3.3
Number of students attending the school in which the participating class is located . .	See Table 3.4
School authority (public or private) . . .	See Table 3.5
Population of the community in which the school is located	See Table 3.6
Type of community	See Table 3.7
Weekly time allottment for the course of the participating class. . .	See Table 3.8
Sex of the teacher of the participating class	See Table 3.9
Total teaching experience of the teacher of the participating class. .	See Table 3.10
Teacher's experience in teaching the science subject of the participating class . .	See Table 3.11

As is shown in the cited tables, there were no significant differences between the experimental group and the control group on the variables checked. Since the classes were randomly assigned to either the experimental group or to the control group, we would expect differences to arise only by chance. We assume that any other characteristic for which a check was not made was randomly distributed between the experimental and control groups.

Table 3.2

Number of Students Enrolled in the Participating Classes

	Exper.	Control	Total
20 or less	5	7	12
21 - 25	20	16	36
26 - 30	14	17	31
31 or more	14	15	29
$\chi^2 = 1.068$	53	55	108
ndf = 3			
Not significant (.05)			

Table 3.3

Selection of Students for the Participating Classes

	Exper.	Control	Total
College Preparatory Curriculum	36	34	70
No Selection	17	21	38
	53	55	108
$\chi^2 = 0.444$			
ndf = 1			
Not significant (.05)			

Table 3.4

Number of Students Attending the Schools in which the Participating Classes are Located

	Exper.	Control	Total
Less than 600	9	12	21
600 - 1199	16	14	30
1200 - 1799	15	12	27
1800 - 2399	7	14	21
2400 or more	6	3	9
$\chi^2 = 4.193$ ndf = 4 Not significant (.05)	53	55	108

Table 3.5

Authority of the Schools in which the Participating Classes are Located

	Exper.	Control	Total
Public	46	50	96
Private	7	5	12
$\chi^2 = 0.464$ ndf = 1 Not significant (.05)	53	55	108

Table 3.6

Population of the Communities in which the Schools of the Participating Classes are Located

	Exper.	Control	Total
Less than 10,000	11	10	21
10,000 - 19,999	6	8	14
20,000 - 40,999	13	11	24
50,000 - 99,999	5	7	12
100,000 - or more	18	19	37
$\chi^2 = 0.824$	53	55	108
ndf = 4			
Not significant (.05)			

Table 3.7

Type of Communities in which the Schools of the Participating Classes are Located

	Exper.	Control	Total
Primarily Industrial	23	27	50
Primarily Residential	24	22	46
Primarily Agricultural	6	6	12
	53	55	108
$\chi^2 = 0.380$			
ndf = 2			
Not significant (.05)			

Table 3.8

Weekly Time Allotments for the Course of the Participating Classes*

Minutes per Week	Exper.	Control	Total
225 or less	9	8	17
226 - 275	26	27	53
276 - 330	13	11	24
331 or more	4	7	11
χ^2 = 1.064 ndf = 3 Not significant (.05)	52	53	105

* Information not obtained for three classes.

Table 3.9

Sex of the Teachers of the Participating Classes

	Exper.	Control	Total
Male	46	40	86
Female	7	15	22
χ^2 = 3.28 ndf = 1 Not significant (.05)	53	55	108

Table 3.10

Total Teaching Experience

of the Teachers of the Participating Classes*

	Exper.	Control	Total
5 years or less	9	17	26
6 to 10 years	16	11	27
11 to 20 years	15	12	27
More than 20 years	12	14	26
χ^2 = 3.84 ndf = 3 Not significant (.05)	52	54	106

* Information not obtained from two teachers.

Table 3.11

Teacher's Experience in Teaching

the Science Subject of the Participating Classes*

	Exper.	Control	Total
3 years or less	15	18	33
4 to 6 years	20	10	30
7 to 15 years	10	16	26
More than 15 years	7	10	17
χ^2 = 5.49 ndf = 3 Not significant (.05)	52	54	106

* Information not obtained from two teachers.

3. Timetable of the Project.

As already mentioned, the HOSC Instruction Project was carried out during the school year 1960-1961. The outline below summarizes the timing of the major activities of the Project.

1960-61

1 September	Questionnaire Number 1 mailed to all teachers.
20 September to 14 October	Administration of pre-tests to all classes. The pre-test battery included (1) the criterion instrument, *Test On Understanding Science*, and (2) the *Otis Mental Ability Test.*
17 October to 10 March	EXPERIMENTAL PERIOD. *Experimental Group*: Teachers taught two units by the HOSC Instruction Method during this period. Each HOSC unit required approximately two weeks of class time. *Control Group*: Teachers taught their classes during this period as they normally do, with the restriction that they did not use the HOSC Instruction Method.
1 February	Questionnaire Number 2 mailed to all teachers.
10 March to 24 March	Administration of post-test "A" to all classes. Post-test "A" consisted of the criterion instrument, *Test On Understanding Science*.
13 March	Questionnaire Number 3 mailed to teachers of classes in the experimental group.
14 April to 28 April	Administration of post-test "B" to all classes. Post-test "B" consisted of a standardized test in the science subject (biology, chemistry, or physics) of each class's course.
May-June	HOSC Instruction Method units made available to classes in the control group.

In the ensuing subsections, we shall give the pertinent information about each major Project activity listed above.

4. Pre-Tests.

The organization of test adminstrators, as previously described, at the Regional Centers and elsewhere proved to be quite effective, so that it was possible to complete the pre-testing of all participating classes[1] between 20 September and 14 October 1960. The administration of the pre-test battery required two class periods and included two tests, given in this order at every administration: (1) the criterion instrument, Test On Understanding Science, Form X, and (2) the Otis Quick-Scoring Mental Ability Tests: Gamma Test, Form Am. Both tests were taken by a total of 2808 students in the experimental and control groups.[2] This represents 97.13% of the total enrollment of 2891 students in the experimental and control classes at the time of the pre-tests. The remaining 2.87% of the students took only one or the other of the pre-tests or were absent when both tests were administered.

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[1] Actually, one test administrator who had agreed to give the pre-tests failed to do so. This one instance (out of more than one hundred that might have misfired) was not detected until after the experimental period had begun, and it therefore became necessary to delete the affected physics class in the experimental group from the main analyses.

[2] An additional 202 students in "Experimental Group B" also took both pre-tests.

Since the Otis Mental Ability Tests[1] are well-known, it is not necessary to give a lengthy description of this instrument. The Gamma Test is designed for high school and college students, and Form Am may be used when either hand-scoring or machine-scoring is desired. In the Project pre-testing, Form Am was used with separate answer sheets, which were later scored by a mark-sensing machine.

The Test On Understanding Science (TOUS)[2] is a relatively new research instrument, and we shall describe it briefly. Form X consists of sixty four-alternative, multiple-choice items. The items and directions are printed in a 14-page test booklet, and students mark their choice of the best answer to each item on a separate answer sheet, which is designed for hand-scoring or machine-scoring. A student's total score on TOUS is the number of items answered correctly. TOUS also gives three scale scores, since each of the sixty items is assigned to one of three scales, which have the following designations:

Scale 1 - Understandings about the scientific enterprise. (18 items)

Scale 2 - Understandings about scientists. (18 items)

Scale 3 - Understandings about the methods and aims of science. (24 items)

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[1] Published by World Book Company, Yonkers-on-Hudson, New York. The Gamma Test, Form Am, is copyrighted 1937 by World Book Co.

[2] Published by Educational Testing Service, Princeton, New Jersey. Form X is copyrighted 1960 by W.W. Cooley and L.E. Klopfer.

In the original development of TOUS,[1] the understandings pertaining to each of the above scales were analyzed to determine their major components. From this analysis, it was possible to prepare a set of detailed specifications of understandings, which, in the aggregate, provide a sufficiently satisfactory and useable definition of an understanding of science and scientists. The individual specifications were stated as "themes" and represent specific parcels of knowledge, which lend themselves to testing by generally accepted means. With the statements of the themes as a basis, individual multiple-choice test items were prepared. The general principle underlying the construction of items was that if a student understood the ideas expressed in a theme or several connected themes, he would be expected to select the best answer from the alternatives presented.

The items prepared for TOUS were subjected to the customary gauntlet of criticism and evaluation involved in good test construction. The operations included editing of items, consultants' criticism, revision of items, preparation and tryout of preliminary forms, item analysis, and checks on validity and reliability. Experience with TOUS also showed that, when students were exposed to appropriate instruction for a period of several weeks, their scores on TOUS (form pre-test to post-test) tended to improve. Such sensitivity is an eminently desirable characteristic in a research instrument, providing, of course, that the instrument meets accepted standards of reliability and validity.

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[1] The development of TOUS was not carried out as a part of the HOSC Instruction Project. However, since it is a new instrument in an area previously little explored, information about the development of TOUS is included here to indicate the approach used to testing in this area and to testify to the appropriateness of employing TOUS as the criterion instrument of the Project.

Perhaps the best indication we can give of the nature and content of TOUS Form X, is to reproduce some representative items from the test. We do so below, and also give the scale to which each of the sample items was assigned.

Item 7. (Scale 1)

The microscope came into wide use in scientific work in the 17th century. This new instrument made it possible for scientists to see very small objects, and also to

A. look more closely at the ultimate nature of matter.
B. discover the real meaning of life.
C. look more closely at cause and effect relationships.
D. explore new problems unknown before this time.

Item 16. (Scale 3)

Which one of the following statements best describes the most important way that scientists contribute to our society?

A. They provide knowledge about nature.
B. They make improved products for better living.
C. They provide skilled services or advice to others.
D. They show us what we should strive for.

Item 19. (Scale 1)

If a physicist and a livestock dealer were to walk into an experimental biology laboratory together for the first time, which man would probably understand what was going on there more quickly?

A. Both men would understand at about the same time, because neither of them is a research biologist.
B. The livestock dealer, because, the training for his job most likely included the methods of experimental biology.
C. The physicist, because biologists and physicists have similar points of view toward investigating natural phenomena.
D. The physicist, because physicists do the same kind of laboratory work that biologists do.

Item 42. (Scale 2)

In regard to intelligence, most scientists

A. have about average intelligence.
B. are born with a special scientific aptitude.
C. are smart because of their special training.
D. have more than average intelligence.

Item 45. (Scale 3)

When some of the facts in a certain area of science are not explained by an existing theory, scientists

A. may revise the unexplained facts so that they will fit into the theory.
B. may modify the theory so that more of the facts will be explained.
C. should discard the theory and formulate a new one immediately.
D. should show the theory to be in error in all cases.

Item 47. (Scale 2)

Bill always makes good grades in school, but is a practical joker. Frank also makes good grades but has no sense of humor. Janet is a serious, intelligent, and popular girl. Who would be most likely to become a research scientist?

A. Frank
B. Janet
C. either of the boys
D. any one of the three

Item 50. (Scale 3)

Ralph said: "Scientists do experiments to ask questions of nature." The best interpretation of Ralph's statement is that experiments and tests are used in science to

A. prove the regularity of nature.
B. learn by trial and error.
C. check predictions made from scientists' observations and ideas.
D. inquire into the mystery of creation.

From the foregoing discussion and sample items, it should be clear why TOUS was considered to be an appropriate criterion instrument for the HOSC Instruction Project. First, TOUS was an instrument which attempted to measure for the "intangible" objectives that are the substance of the discussion in chapter I of this report. Second, and not unexpectedly, the areas of understandings about science and scientists covered by TOUS coincided quite well with the major objectives (delineated as "category C" objectives in chapter II, section B) of the HOSC Instruction Method units. Thus, TOUS could be utilized to evaluate the extent to which these objectives had been attained by students as a result of studying the HOSC units. Moreover, TOUS provided three scale scores, so that it would be possible to obtain information on the relative effectiveness of the HOSC Instruction Method units in the three corresponding areas of understanding. Lastly, it is only just to add that our choice in selecting a criterion instrument was quite limited, since we know of no other test which attempts to evaluate student understandings about science and scientists as comprehensively as TOUS.

In concluding this subsection on the pre-tests, we should point out that every effort was made to assure that the teachers of the participating classes did not have an opportunity to study TOUS, the criterion instrument, at the time that the pre-tests were administered. We believe that any biasing of the experiment that might have been introduced from this source was eliminated by the use of outside test administrators and the subsequent return of every copy of TOUS. The criterion instrument was not available for study to any teacher until the time of the post-test.

5. Questionnaire Number 1

Questionnaire Number 1, together with an appropriate covering letter and stamped return envelope, was mailed to all teachers on 1 September 1960, so that it would arrive in the schools at the beginning of the Fall 1960-61 semester. This was a rather difficult, five-page questionnaire, requiring an estimated time of one hour to complete. One month after mailing, the return of completed questionnaires was only 79%. Follow-up letters resulted in the eventual submission of completed questionnaires from all but three teachers, or a return of 97%.[1]

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[1] In addition to these 105 questionnaires from the teachers of the experimental and control classes, eight questionnaires were returned by the teachers of classes in "Experimental Group B". All 113 questionnaires were used in the rating procedures which are discussed below.

Page 1 of Questionnaire Number 1 asked for information about the participating class, about the school and community, and about the academic background of the teacher. This information was used primarily to check on the comparability of the experimental group and the control group. The information obtained was tabulated and has been presented earlier in this chapter. However, the more significant part of Questionnaire Number 1 was contained in pages 2 to 5, which are reproduced on the next four pages. Although it was not stated quite so explicitly in the instructions, there were two purposes for this part of the questionnaire: first, to obtain a comparative measure of the teachers' understanding of the scientific enterprise, of scientists, and of the methods and aims of science; and, second, to collect responses to certain leading questions in the form of short essays, which could be used as a focal point in the development of a possible evaluation instrument that would assess the understanding of science and scientists by high school science teachers. (It was not feasible to pursue further the second purpose, the development of an evaluation instrument, in connection with the HOSC Instruction Project. Hence, the ensuing discussion will concentrate on the achievement of the first purpose of the latter part of Questionnaire Number 1.)

IV. Instructions for Completing Pages 3, 4, and 5.

As you know, much concern has frequently been expressed about the general knowledge which science teachers have concerning science and scientists. As often happens, there has been much talk about this point, but there is virtually no objective evidence. One aspect of the HOSC Instruction Project is the development of an evaluation instrument for assessing science teachers' understanding of the scientific enterprise, of scientists, and of scientific methods.

An important step in developing such an instrument is to obtain the responses of a group of science teachers to appropriate questions pertaining to the area of knowledge that the instrument is to evaluate. We hope that you would be willing to co-operate in such an undertaking by writing brief, essay-type answers to the questions on the following three pages.

If you are familiar with the mechanics of test construction, you know that essay responses provide a rich source for suitable alternative answers to objective-type test items. One use which we would like to make of your brief essay responses is the design of such an objective test for science teachers like yourself.

The questions to which we would like you to write your brief, essay-type responses are rather general. Lengthy books might perhaps be written about each of them, but that is not our intent. We would like you to give some thought to each of the questions, and then write a brief essay response in the space provided under the question. (Use the reverse side of the page if necessary.) The entire writing task should not take more than about 40 minutes of your time.

Since this is not a writing contest, we would like to assure you that your essay responses will not be used to judge your writing style or your skill in English composition. On the contrary, your essays will be used only in the HOSC Instruction Project. Please return your responses to the nine questions on pages 3, 4, and 5 as a part of Questionnaire Number 1.

Thank you for your help.

2

A. Questions on the Scientific Enterprise.

1. What are the main ways in which scientists communicate with one another?

2. It seems clear that the results of science definitely affect the cultures in which science flourishes. Do you feel that the reverse is also true, that is, is scientific investigation affected by the culture in which it is carried on? -- (Please support your answer with examples, if possible.)

3. What are the principal functions of scientific societies?

B. Questions on Scientists.

1. What are scientists like as people? -- (Please describe those generalizations which can be made regarding this important question.)

2. What are examples of scientific attitudes, and why do scientists have them?

3. What special abilities does a person need to be an effective scientist?

Questionnaire Number 1. Page 5 [ ]

C. Questions on the Methods and Aims of Science.

1. The following six steps of the scientific method are listed in a certain science textbook:
   (1) Stating a problem.
   (2) Suggesting a guess or hypothesis.
   (3) Careful planning of experiments.
   (4) Collecting the facts.
   (5) Drawing conclusions.
   (6) Applying the new knowledge.

   Do you think this is a satisfactory way of describing the procedures which scientists use? If not, why not?

2. In what ways do theories assist the scientist in his work?

3. "The basic aim of science is to produce better things for a better life." -- If you agree with this statement, explain why you agree. If you disagree, explain why you disagree.

In formulating the experimental design of the Project (--see section A, above--), it was recognized that a possible source of differences in the effectiveness of the HOSC Instruction Method, or for that matter the effectiveness of any instructional technique, would be differences in the classroom teacher's understanding of science and scientists. Testing the teachers in the Project for such understanding was impractical, even if a satisfactory test for teachers had been available. Thus, we turned to a questionnaire, which could be rated with some objectivity, to obtain the desired comparative measure. Examination of pages 3,4, and 5 of Questionnaire Number 1 reveals that the headings on these pages, as well as the questions under them, correspond to the three areas of understandings from the specifications prepared in the development of the Test On Understanding Science (TOUS). (--see subsection 4, above--) Consequently, these three pages of Questionnaire Number 1 also correspond to the three scales of TOUS.

As in the construction of test items for TOUS, the questions of Questionnaire Number 1 were derived directly from the several themes in the specifications of understandings about the scientific enterprise (Area I), about scientists (Area II), and about the methods and aims of science (Area III). The TOUS themes in the specifications of understandings later also served as a basis for rating the responses to the questions given by the teachers.

The rating was done in the following manner. A pair of code letters was assigned at random to each completed Questionnaire Number 1, and only the code letters were written on pages 3, 4, and 5 for later identification. The pages of the questionnaire were then separated and reassembled in three piles, corresponding to Areas I, II, and III. For each of the three questions in each area, a three-point rating key was determined, based on the TOUS themes and on representative responses. Using the rating keys, two graduate students independently rated the response to each question as 3, 2, or 1 (high to low). The ratings given to the responses to the three questions in each area were added to yield a rating for the area, ranging from 9 to 3 (high to low).

The rating scheme proved to be satisfactory. In no instance did the area rating arrived at by the two independent raters differ by more than two points. The product-moment correlations of the area ratings given by the two raters were:

Area I r = .72
Area II r = .67
Area III r = .73

The arithmetic mean of the area ratings given by the two raters was found and taken as the "teacher's area rating" in each of the three areas. The distributions, which are approximately normal, of teacher's area ratings in Area I, Area II, and Area III are shown in Table 3.12, Table 3.13, and Table 3.14, respectively. By combining the extremes of the distributions, a ten-point scale, running from 9 to 0 (high to low), was obtained. These "teacher's area scale ratings" are shown in the last column of each table.

To obtain a composite, or total, rating for each teacher, his three area scale ratings were summed. This yielded a "teacher's total rating," ranging from 27 to 0. The distribution of teacher's total ratings is shown in Table 3.15, which also shows how a ten-point scale, running from 9 to 0, of "teacher's total scale ratings" was obtained.

From the foregoing description, it is apparent that our rating and scaling procedures did not attempt to produce an absolute measure of a teacher's understanding of science and scientists. Indeed, this would be virtually impossible without an appropriate, previously-constructed, acceptable test. However, we believe that we were successful in obtaining useful comparative measures of the participating teachers' understandings in the three defined areas and in a composite total. For the purpose of the Project analyses, this was all that was required.

Table 3.12

Distribution of Teacher's Area I Ratings:- Understandings about the Scientific Enterprise

Area Rating	Number of Teachers	Percent	Area Scale Rating
9	2	1.8	9
8.5	3	2.7	
8	9	8.0	
7.5	10	8.9	8
7	18	15.9	7
6.5	13	11.5	6
6	16	14.2	5
5.5	13	11.5	4
5	12	10.6	3
4.5	7	6.2	2
4	7	6.2	1
3.5	3	2.7	0
	113	100.2	

Table 3.13

Distribution of Teacher's Area II Ratings:- Understandings about Scientists

Area Rating	Number of Teachers	Percent	Area Scale Rating
8	3	2.7	9
7.5	2	1.8	
7	6	5.3	8
6.5	8	7.1	7
6	12	10.6	6
5.5	15	13.2	5
5	17	15.0	4
4.5	18	15.9	3
4	20	17.7	2
3.5	5	4.4	1
3	7	6.2	0
	113	99.9	

Table 3.14

Distribution of Teacher's Area III Ratings:-

Understandings about the Methods and Aims of Science

Area Rating	Number of Teachers	Percent	Area Scale Rating
9	1	0.9	9
8.5	1	0.9	
8	6	5.3	
7.5	5	4.4	8
7	5	4.4	7
6.5	12	10.6	6
6	15	13.2	5
5.5	18	15.9	4
5	16	14.2	3
4.5	9	8.0	2
4	14	12.4	1
3.5	9	8.0	0
3	2	1.8	
	113	100.0	

Table 3.15

Distribution of Teacher's Total Ratings:-
Understanding of Science and Scientists

Total Rating	Number of Teachers	Percent	Total Scale Rating
27	2	1.8	9
26	1	0.9	
25	1	0.9	
24	0	0	8
23	2	1.8	
22	2	1.8	
21	2	1.8	7
20	2	1.8	
19	10	8.9	6
18	9	8.0	
17	1	0.9	
16	2	1.8	5
15	7	6.2	
14	10	8.9	
13	9	8.0	4
12	10	8.9	
11	7	6.2	3
10	6	5.3	
9	5	4.4	
8	10	8.9	2
7	6	5.3	
6	3	2.7	1
5	2	1.8	
4	0	0	
3	2	1.8	0
2	2	1.8	
	113	100.6	

5. Experimental Period

After the completion of the pre-testing, the experimental period of the Project began and extended from approximately 17 October 1960 through 10 March 1961[1]. During this period, the teachers of the participating classes in the experimental group were asked to teach two units by the HOSC Instruction Method. The teachers of classes in the control group taught their classes as they normally do, with the restriction that they did not use the HOSC Instruction Method.

Teachers of experimental group classes in biology and physics were given a choice in selecting two HOSC units, from the three available in each subject, that would best fit into their teaching schedules. Teachers of experimental group classes in chemistry could not be given this choice, since there were only two HOSC units in chemistry available. The decisions concerning the scheduling and the order of teaching the two HOSC units were left with the individual teachers. Reports returned by the teachers indicate that virtually all the HOSC units were taught during ten class periods plus one additional period devoted to the unit test, or a total time of approximately two school weeks.

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[1] It should be remarked that, due to delays in the pre-testing and in the printing of the Case booklets, it was necessary to postpone the beginning of the experimental period by approximately three weeks from the time that was originally planned. The closing of the experimental period also was moved back accordingly.

From the point of view of the center of the Project at Cambridge, much of the experimental period was devoted to a mammoth mailing operation. The reproduction, assembling, and packaging of materials for distribution to the experimental group classes was a major task. For each HOSC unit, a package containing the Case booklets and a second package, often a third, containing the Teaching Kit materials were sent out. All told, some 250 packages, each one individually prepared according to the needs of the class, were distributed.

Included with the Teaching Kit for each unit were copies of the unit test (--see chapter II, section C --) sufficient for the students in the class. The unit tests were administered by the classroom teacher and were scored by the teacher, by the use of a key furnished with the tests. After the tests were scored and discussed in class, the set of unit tests was mailed back to Cambridge in a postage prepaid envelope. The receipt of the unit tests, which could later be used to glean additional information, enabled us to gauge the progress being made in teaching the required two HOSC units. Primarily through this mechanism, we learned that three classes in the experimental group had used only one HOSC unit. Since these classes did not follow out the conditions of the experiment, it became necessary to drop them from the main analyses. Fortunately, there was only one class in biology, one class in chemistry, and one class in physics that had to be dropped for this reason[1].

During the experimental period, the scoring of the pretests was accomplished and the processing of these data was begun. (All data processing will be described in section C, below.) The other activities of this period, which are not covered elsewhere, need be summarized only briefly:

(a) The principal investigator made single classroom visits to the four experimental group classes in Massachusetts and one in Connecticut to gain impressions and to hear student and teacher reactions to the HOSC Instruction Method. The Regional Advisers were encouraged to make similar visits to classes in their respective areas, but, due to time pressures, only a few visits were made.

(b) On 17 January 1961, individual letters were sent to all Superintendents of Schools or private school headmasters where a class was participating in the Project. The letter cited the name of the participating teacher and thanked the school system for its cooperation.

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[1] Only one teacher, the teacher of the dropped chemistry class, failed to teach the second HOSC unit because of dissatisfaction with the HOSC Instruction Method (--see chapter IV, section C--) The other two instances were due to a breakdown in communication or/and non-delivery of mail.

Enclosed with the letter was a sheet containing suggested copy for a local news release about the Project, and the Superintendent was asked to make use of this if he wished to do so. Subsequently, articles featuring the participating teacher and his role in the Project appeared, to our knowledge, in at least fifteen different newspapers.

(c) On 27 January 1961, a three-page newsletter was sent to all participating teachers. This newsletter reviewed the accomplishments of the Project to date and gave a forecast of the operations to come, highlighting the impending Questionnaire Number 2 and the March and April post-tests.

6. Questionnaire Number 2.

The second questionnaire to be distributed to all participating teachers was mailed, with an appropriate covering letter and return envelope, on 1 February 1961. Questionnaire Number 2 contained four mimeographed pages and was designed so that the respondent needed only to fill in numbers or to check alternatives in answering almost all the questions. With one follow-up, a 100% return of completed questionnaires was obtained from the participating teachers[1].

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[1] At this time, two teachers, one in the experimental group and one in the control group, had withdrawn from the Project. Questionnaire Number 2 was not sent to them. Thus, from the original sample of 108 classes, 106 questionnaires were returned.

The major purpose of Questionnaire Number 2 was to obtain information about the teachers' usual teaching techniques and procedures in relation to the participating classes. Other data gathered with this instrument included each teacher's class load, teaching experience, and use of special teaching materials. Information was also sought concerning the school's library facilities in science. Much of the data gathered in Questionnaire Number 2 is presented in its relevant place elsewhere in the report. Summarized here are the data from section III, School Library Facilities, and section IV, Teaching Techniques.

The responses on the returned questionnaire to the questions on teaching techniques and library facilities were coded and tabulated (-- see Tables 3.16 and 3.17, respectively --). Chi-square tests were applied to disclose any differences between experimental group classes and control group classes. Together with the summary tables, the corresponding pages 3 and 2 of Questionnaire Number 2 are reproduced below.

The data summarized in Table 3.16 provide some interesting insights into teaching techniques generally used in high school science teaching, at least insofar as our sample is representative of present-day biology, chemistry, and physics classes. For example, we note that, in more than one-fourth of all classes, 50% or more of the students' class time is generally devoted to listening to lectures (item 27); in two-fifths of all classes, the use of demonstrations generally occupies 7%

or less of total class time (item 28); the median amount of time for all classes spent in individual student laboratory work lies between 18% and 22% (item 29). Remarks about the implications of these and other revealing data for high school science teaching in general lie outside the scope of this report.

In regard to the present study, the data in Table 3.16 give us considerable information about the activities that were carried on in the participating classes, both in the experimental group and in the control group. The classes in both groups were involved in the same types of instructional activities for similar amounts of total class time (--Chi-squares are not significant at the .05 level.--), with the following two exceptions:

> (a) The classes in the experimental group appear to have spent somewhat more total class time in reading from textbooks (item 34) than the classes in the control group (--Chi-square is significant at the .02 level.--). Using the mid-points of the percentage intervals of Table 3.16, we can estimate that the mean total class time spent in reading from textbooks was 3.52% for the classes in the experimental and 1.63% for the classes in the control group. It is quite likely that the use of the HOSC Instruction Method by the experimental group classes in itself accounts for the difference. Many teachers may have had their students read and study the Case booklets in the classroom, and this could increase the amount of class time spent in "reading from textbooks."

IV. Teaching Techniques You Use with the Participating Class.

Taking the school year as a whole, approximately what percentage of the instructional time in class (not counting time for tests and quizzes) do the students of the Participating Class spend in--

(27) listening to lectures ____%

(28) watching demonstrations ____%

(29) individual laboratory work ____%

(30) group discussions ____%

(31) working on problems ____%

(32) watching films or filmstrips ____%

(33) supervised study ____%

(34) reading from textbooks ____%

(35) reading supplementary books or articles ____%

(36) working on projects ____%

*(37) ____________________ ____%

*(38) ____________________ ____%

(Do not make exact calculations; only approximate percentages are necessary.)

(*Specify any other activities in 37 and 38)

(39) On the average, how many hours of homework do you assign per week to students in the Participating Class?

(Please check one.)

___ None
___ about 1
___ about 2
___ about 3
___ about 4
___ about 5
___ about 6
___ about 7
___ about 8
___ more than 8

(40) Additional Comments, if any, on Section IV:

Table 3.16

Teaching Techniques Used in the Participating Classes*

(Source: Questionnaire Number 2)

	Percent of Time Used											
	2% or less	3% to 7%	8% to 12%	13% to 17%	18% to 22%	23% to 27%	28% to 37%	38% to 47%	48% to 57%	58% or more	N	
(Item 27) Listening to Lectures												
Experimental	2	2	8	2	4	2	8	11	7	6	52	X^2 = 12.70
Control	2	1	7	0	10	7	7	3	9	8	54	ndf = 8
Total	4	3	15	2	14	9	15	14	16	14	106	.20> p>.10
(Item 28) Watching Demonstrations												
Experimental	5	13	17	5	10	1	0	0	1	0	52	X^2 = 8.93
Control	8	17	12	7	3	3	1	2	0	1	54	ndf = 5
Total	13	30	29	12	13	4	1	2	1	1	106	.20> p>.10
(Item 29) Individual Laboratory Work												
Experimental	3	2	9	8	9	9	8	1	3	0	52	X^2 = 10.19
Control	3	3	2	15	11	5	6	6	2	1	54	ndf = 6
Total	6	5	11	11	23	20	14	7	5	1	106	.20> p>.10
(Item 30) Group Discussions												
Experimental	10	10	11	4	7	4	3	1	0	2	52	X^2 = 2.83
Control	16	9	11	3	5	2	4	2	1	1	54	ndf = 6
Total	26	19	22	7	12	6	7	3	1	3	106	.90> p>.80
(Item 31) Working on Problems												
Experimental	18	17	10	4	0	1	1	1			52	X^2 = 1.86
Control	15	15	13	5	6	0	0	0			54	ndf = 4
Total	33	32	23	9	6	1	1	1			106	.80> p>.70
(Item 32) Watching Films or Filmstrips												
Experimental	25	19	4	4							52	X^2 = 1.57
Control	26	16	8	4							54	ndf = 3
Total	51	35	12	8							106	.70> p>.60
(Item 33) Supervised Study												
Experimental	35	9	4	2	1	1	0				52	X^2 = 0.16
Control	35	11	4	1	1	0	2				54	ndf = 2
Total	70	20	8	3	2	1	2				106	.95> p>.90

Table 3.16
(continued)

	Percent of Time Used											
	2% or less	3% to 7%	8% to 12%	13% to 17%	18% to 22%	23% to 27%	28% to 37%	38% to 47%	48% to 57%	58% or more	N	
(Item 34) Reading from Textbooks												
Experimental	34	10	5	2	1						52	$\chi^2 = 8.53$
Control	48	4	2	0	0						54	ndf = 2
Total	82	14	7	2	1						106	$.02 > p > .01$
(Item 35) Reading Supplementary Books and Articles												
Experimental	33	15	3	1							52	$\chi^2 = 10.42$
Control	47	3	3	1							54	ndf = 2
Total	80	18	6	2							106	$.01 > p > .001$
(Item 36) Working on Projects												
Experimental	38	12	0	1	1						52	$\chi^2 = 1.64$
Control	45	6	3	0	0						54	ndf = 1
Total	83	18	3	1	1						106	$p = .20$

*In the calculations of chi-squares for this table, adjoining cells with low frequencies in the extremes of the distributions were combined. The reported chi-square in each instance is based on a number of classifications equal to one more than the number of degrees of freedom (ndf) indicated.

(b) The classes in the experimental group appear to have spent somewhat more total class time in reading supplementary books and articles (item 35) than the classes in the control group (--Chi-square is significant at the .01 level.--). Again, using the midpoints of the percentage intervals of Table 3.16, we can estimate that the mean total class time thus spent was 2.94% for the classes in the experimental group and 1.96% for the classes in the control group. This difference is very likely due to the use of the HOSC Instruction Method units, which include the reading of supplementary books and articles, by the experimental group classes.

Since the classes in our sample were randomly assigned either to the experimental or to the control group, we would ordinarily not expect to find significant differences between the two groups in the amounts of total class time spent in various instructional activities. However, it is clear that the two differences which were found are consistent with the known difference in instructional methods used in the experimental and control classes.

We also wish to call attention to the reported percentages of total class time usually spent in group discussions (item 30). For all classes, the median amount of time thus spent lies between 8% and 12%, and an estimate, based on the mid-points of the percentage intervals of Table 3.16, gives approximately 14% for the mean total class time spent in group discussions. The attainment of the objectives of the HOSC Instruction Method relies heavily on this technique (--see chapter II, section B--). In view of the reported amount of time generally spent in group discussions in science classes, the question of whether or not students and teachers generally have sufficient experience with this technique to obtain the maximum benefits from the HOSC units remains open.

Another contributing factor in attaining the maximum effectiveness of the HOSC Instruction Method is the ready availability to students of appropriate collateral reading materials. In this light, the data in Table 3.17 on school library facilities in science are relevant. There are no significant differences in library facilities between the schools of classes in the experimental group and of classes in the control group. Students in both groups use the available facilities to about the same extent. Also, it appears that, as far as numbers of books and periodicals give an indication, there are generally sufficient library resources in the schools of our sample to provide supplementary readings for an instructional method requiring them.

Questionnaire Number 2. Page 2

III School Library Facilities.

(23) How many science books for reference and supplementary reading are available to students in the school library and/or the science department library? (Your estimate is sufficient for this item; on the average, there are ten books in one foot of shelf space.)

(Please check one.)

(0) ___ None
(1) ___ about 25
(2) ___ about 50
(3) ___ about 75
(4) ___ about 100
(5) ___ about 150
(6) ___ about 200
(7) ___ about 250
(8) ___ about 300
(9) ___ more then 300

(24) How many different science periodicals (such as Science Newsletter, Current Science and Aviation, Science World, Chemistry, Scientific American) are generally available to students at the school?

(Please check one.)

___ None
___ 1
___ 2
___ 3
___ 4
___ 5
___ 6
___ 7
___ 8
___ 9 or more

(25) To what extent would you say the students in the Participating Class make use of the available science books and periodicals? (Realizing that students in any group behave differently, you should simply give a general estimate for the class in this item.)

(Please check one.)

(0) ___ never use them
(1) ___ hardly ever use them
(2) ___ use them occasionally
(3) ___ use them frequently
(4) ___ use them extensively

(26) Additional Comments, if any, on Section III:

Table 3.17

Library Facilities in Science of the Schools in which the Participating Classes are Located

(Source: Questionnaire Number 2)

(Item 23) Number of Science Books

	About 50 or less	About 75 to 100	About 150 to 200	About 250 to 300	More than 300	Total	No Response
Experimental	5	4	10	6	26	51	1
Control	10	7	7	11	18	53	1
Total	15	11	17	17	44	104	2

$\chi^2 = 5.90$ ndf = 4 $p = .20$

(Item 24) Number of Science Periodicals

	3 or less	4	5	6	7	8	9 or more	Total	No Response
Experimental	3	3	10	5	6	7	17	51	1
Control	8	5	13	1	13	4	9	53	1
Total	11	8	23	6	19	11	26	104	2

$\chi^2 = 11.65$ ndf = 6 $.10 > p > .05$

(Item 25) Extent to which Students Use Library Books and Periodicals

	Never or Hardly ever	Occasionally	Frequently	Extensively	Total	No Response
Experimental	6	30	12	3	51	1
Control	9	29	12	4	54	0
Total	15	59	24	7	105	1

$\chi^2 = 0.68$ ndf = 3 $.90 > p > .80$

7. Post-Test "A"

During the last week of February 1961, arrangements were completed for the administration of post-test "A" to all participating classes. Primarily for reasons of economy, we decided to utilize outside test administrators only for those classes located within the convenient reach of the Regional Centers. For the classes not so located, the classroom teachers were asked to administer post-test "A" to their classes. The result of this decision was that post-test "A" was administered to 35 classes by the classroom teachers and to the remainder by outside test administrators. In all instances, the person doing the testing was furnished with detailed instructions on procedure, test booklets, answer sheets, pencils, and report forms. Where the classroom teacher gave the test, these materials were sent directly by mail, while the outside test administrators received them through their respective Regional Advisers.

The period for administering post-test "A" extended from 10 March to 24 March 1961. Post-test "A" required one class period and consisted of the criterion instrument, TOUS, previously described (--see subsection 4, above--). All teachers were told that their students were not to be given any special prior preparation for the test. A total of 2615 students in the experimental and control groups[1] took the test. As soon as the test was administered, the students' answer sheets were mailed back to Cambridge for scoring. The Reports of Test Administration received with each set of answer sheets indicated that there were no unusual occurrences and that the tests were properly administered at every testing session.

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[1] An additional 143 students in "Experimental Group B" also took post-test "A".

B. Questionnaire Number 3

To elicit teachers' opinions about and anecdotal evaluations of the HOSC Instruction Method and its materials, Questionnaire Number 3 was mailed on 13 March 1961 to all teachers of classes in the experimental group. This four-page mimeographed questionnaire consisted of leading questions about the HOSC Instruction Method, the two HOSC units taught, and the supplementary materials. With one of follow-up, a total of 47 experimental group teachers, or 89%, returned completed questionnaires. The breakdown of returned questionnaires by science subject was: biology- 17 (89%), chemistry- 19 (100%), physics- 11 (73%).

The questions asked in Questionnaire Number 3 are reproduced on the next two pages. A summary of the teachers' replies will be given in its proper place in chapter IV, section C.

Questionnaire Number 3 ( ) Page 1

- -

I. Reactions to the HOSC Instruction Method.

LEADING QUESTIONS:

(11) Did you like or dislike teaching by the HOSC Instruction Method?

(12) Did you notice any shortcomings in using this method of instruction with high school students?

(13) If the materials became generally available, would you use the HOSC Instruction Method as a part of your teaching in the future?

……

Questionnaire Number 3 ( ) Page 2

- -

II. Comments on the First HOSC Unit Taught.

Case Number and Title: ________________________________

Number of class periods spent on this unit: ________

LEADING QUESTIONS:

(21) What was good in this unit?

(22) What aspects of this unit need to be improved?

(23) To what extent do you feel the Objectives for the Unit (see pages II-1 and II-2 of the Teacher's Guide) were achieved?

(24) Do you feel that your students obtained any "intangible" benefits, which were not measured by our tests, from their study of this unit?

Questionnaire Number 3. ( ) Page 3

- -

III. Comments on the Second HOSC Unit Taught.

Case Number and Title: ______________

Number of class periods spent on this unit: ________

LEADING QUESTIONS:

(31) What was good in this unit?

(32) What aspects of this unit need to be improved?

(33) To what extent do you feel the Objectives for the Unit (see pages II-1 and II-2 of the Teacher's Guide) were achieved?

(34) Did this unit "go" easier or harder than the first one?

……

Questionnaire Number 3. ( ) Page 4

- -

IV. Comments on the Teacher's Guides and Teaching Kit Items.

LEADING QUESTIONS:

(41) Were the Teacher's Guides useful in teaching the HOSC units?

(42) What should be omitted from the Guides? What might be added?

(43) Which Teaching Kit items were particularly valuable to you?

(44) Which Teaching Kit items were of no value or of little value?

(45) What additional Teaching Kit items might be useful?

9. Post-Test "B"

The period for administering post-test "B" extended from 14 April to 28 April 1961. Since post-test "B" consisted of a standardized achievement test in the usual content of the science course, a period as late in the school year as was feasible was selected to minimize the differences in science subject-matter covered by the various classes due to the presentation of the usual topics of a course in varying sequences by different teachers. Post-test "B" was administered by the participating teachers to their own classes. Detailed instructions on procedure and testing materials were distributed by mail. All teachers were instructed that their classes should be informed about the test several days in advance of the testing day, but that no special review of the course material should be given prior to the test.

The achievement tests selected for post-test "B" for the participating classes in the respective science subject courses were Cooperative Biology Test, Form Y;[1] Cooperative Chemistry Test, Form Z;[2] and Cooperative Physics Test, Form Z.[3] This series of tests is well-known and has been adequately standardized.[4]

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[1] Published by Cooperative Test Division, Educational Testing Service, Princeton, New Jersey. Copyright 1948.

[2] Same publisher. Copyright 1950.

[3] Same publisher. Copyright 1950.

[4] For information about this series, refer to The Cooperative Tests: Manual of Directions, (Princeton, N. J.: Educational Testing Service, 1951)

The tests are designed to be used with separate answer sheets, and each test can be administered in one class period. Post-test "B" was administered to 1069 students in biology, 945 students in chemistry, and 576 students in physics, or a total of 2590 students. The Reports of Test Administration submitted by the teachers indicate that the tests were properly administered in every instance.

Included with the testing materials sent to each teacher were a scoring stencil and scoring directions, so that he might score his students papers if he wished to do so. About 65 % of the teachers elected to score the papers for their classes. All student answer sheets from post-test "B" were mailed back to Cambridge, where they were scored or the teachers' scoring was checked, as was necessary.

10. Activities of May and June

After the completion of both post-tests, the HOSC Instruction Method units were made available to the teachers of classes in the control group. These teachers had received sample copies of the Cases along with the materials for post-test "B" and were asked to select the HOSC units which they wished to use with their classes. Requests for 23 units were received from control group teachers, and the required sets of Case booklets and Teaching Kits were distributed.

A memorandum of thanks was sent to all participating teachers on 22 May 1961. Also, on 25 May 1961. Professor Fletcher G. Watson. Consultant to the Project, sent a personal letter of appreciation to every teacher. A carbon copy of this letter was sent to the teacher's principal. Early in June, each teacher received a small classroom library of paperbound science books, as a token of appreciation for his participation in the HOSC Instruction Project.

D. DATA PROCESSING

A few words are in order concerning the techniques used in processing the data collected in the Project. In our data processing, we utilized the IBM facilities at Harvard and at the Massachusetts Institute of Technology. A three-digit class code was assigned to each participating class. Every student within each class was assigned a two-digit identification number. Thus, a five-digit number (student ID) served to identify every student in the Project. This ID was entered on every test paper and answer sheet received from that student. A combination class roster and coding sheet was prepared for each participating class. This sheet contained columns for entering each student's name, ID, grade, sex, and all test scores.

The scores for every student on the several tests of the Project were obtained as follows:

(a) The answer sheets of the Otis Mental Ability Test were scored by mark-sensing machine (appropriately checked by hand-scoring). Each student's Otis raw score was transcribed to the coding scheets.

(b) TOUS was scored by means of a special computer program. IBM cards were punched for every TOUS answer sheet received, verified, and prepared for computer input. The computer output provided the three scale scores and a total score for each TOUS answer sheet.

(c) The unit tests from the experimental group classes were originally scored by the classroom teachers. Each set of papers was spot-checked for accuracy and consistency, and the students' scores were then transcribed to the coding sheets.

(d) The Cooperative Tests (post-test "B") were hand-scored and the scoring was checked by a second person. The raw scores ($= \text{Right} - \frac{\text{Wrong}}{4}$) were converted to scale scores, which were transcribed to the coding sheets.

A "student summary card" was punched for every student from the information on the coding sheets. Each card contained the student ID, grade, sex, and the following scores: TOUS post-test (3 scale scores and total), TOUS pre-test, Otis raw score, subject test score (Coop scale score), and unit test scores (for experimental group only). For each class, the scores on the student summary cards, except the unit test scores, were added, and the means were calculated.

Finally, a "class means summary card" was punched for each class. In addition to all necessary class mean scores, this card contained the three teacher's area scale ratings and teacher's total scale rating, which were derived from Questionnaire Number 1. The set of class means summary cards provided the desired computer input for the analyses which we shall discuss in the next chapter.

Chapter 1V. Findings.

The data of the HOSC Instruction Project were used in two series of analyses, viz., the main analyses of the HOSC Instruction Method and the subject test analyses. In both series of analyses, the statistical model employed was the analysis of variance with covariance adjustment. Class means, rather than individual student scores, were used as the unit of analysis, since it was the participating classes, not the individual students, which had been randomly assigned either to the experimental or to the control treatment[1] at the outset of the Project.

A. MAIN ANALYSES

In this series of analysos, the null hypothesis under test was:

> There are no significant differences in understanding of science and scientists between students who have studied under the HOSC Instruction Method as part of their regular science class work and students who have not.

Since the criterion instrument, the Test On Understanding Science (TOUS), yielded a total score and three scale scores, it was possible to carry out four corresponding analyses.

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[1] For a discussion of the groups-within-treatments design, see chapter 7 in E. F. Lindquist, Design and Analysis of Experiments in Psychology and Education, (Boston: Houghton, Mifflin Co., 1953).

We hypothesized that portions of the variance in the TOUS post-test class means would be explained by:

(A) whether the class was in the experimental or in the control group (method effect);

(3) whether the teacher of the class rated high or low in his understanding of science and scientists (teacher rating effect); and

(C) whether the class was taking a course in biology, chemistry, or physics (science course effect).

Thus, the analysis of variance design was stratified according to to these three effects. Two levels are indicated for the first effect, two for the second, and three for the third, resulting in a 2 x 2 x 3 design. TOUS post-test scores might also be a function of (1) TOUS pre-test scores and of (2) general scholastic aptitude scores, and these were introduced as covariance controls.

The equation for the difference of a TOUS post-test class mean (Y) from the grand mean of the TOUS post-test (μ) may be given as

$$(Y_{stui} - \mu) = A_s + B_t + C_u + D_{st} + E_{su} + G_{stu} + b_1(X_{1i} - \bar{X}_1) + b_2(X_{2i} - \bar{X}_2) + e_{stui}$$

where A, B, and C are the principal effects specified above;

D, E, F, and G are the interaction effects;

X_1 and X_2 are the class means on the two covariance controls, TOUS pre-test and scholastic aptitude;

$\bar{X}_1$ and $\bar{X}_2$ are the grand means of the two covariance controls;

b_1 and b_2 are the regression coefficients of the respective covariance controls; and

e_{stui} is the error, or unexplained variation of Y_{stui} from μ.

In the main analyses, the sample available included 100 of the original 108 classes participating in the experiment. A summary of the participating classes included in the analyses and the reasons for deleting each of the eight classes is given below.

Biology - Experimental (17 of original 19)
Delete: (151)[1] Questionnaire Number 1 not returned; hence, no rating of teacher's understanding of science and scientists was obtained.
(184) Teacher taught only one HOSC unit.

Biology - Control (20 of original 22)
Delete: (235) Teacher withdrew before post-tests.
(253) Questionnaire Number 1 not returned.

Chemistry - Experimental (18 of original 19)
Delete: (368) Teacher taught only one HOSC unit and withdrew before post-tests.

Chemistry - Control (20 of original 20)
Delete: none

Physics - Experimental (13 of original 15)
Delete: (532) Teacher taught only one HOSC unit.
(533) Pre-test data were not obtained.

Physics - Control (12 of original 13)
Delete: (693) Questionnaire Number 1 not returned and teacher withdrew before post-tests.

In the following five subsections, we present the results of the main analyses and a summary of these findings.

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[1] The three-digit figures in parentheses are class code numbers.

1. TOUS Total Analysis

In this analysis, as in the three succeeding ones, effect A (--see above--) is the primary treatment effect, with two "levels": (1) HOSC Instruction Method, (2) control. The two levels of effect B, teacher rating, are: (1) high, (2) low. The three categories of effect C, science course of the class, are: (1) biology, (2) chemistry, (3) physics. The second covariance control, X_2, is the class mean of the raw scores on the Otis Mental Ability Test.

In the TOUS total analysis, the criterion variable, Y_{stu}, is the class mean of the post-test TOUS total scores. The first covariance control, X_1, is the class mean of the pre-test TOUS total scores. The two levels of effect B were obtained by dichotomizing the teacher's total scale ratings (--see Table 3.15--), so that "low" equalled a scale rating from 0 to 4 and "high" equalled a scale rating from 5 to 9.

To meet the requirement of proportionality among all the cells in the design, it was necessary to discard some classes. With the given number of classes falling in each cell, the maximum possible number of classes that could be included in this analysis was 80. The following ratios among cells were used:

(A) experimental : control = 1 : 1

(B) high rating : low rating = 2 : 3

(C) biology : chemistry : physics = 3 : 3 : 2

The classes to be included in the analysis were randomly selected for each cell. Table 4.1 gives the number of classes in each cell of the design for this analysis.

Table 4.2 is the analysis of variance table for the TOUS total score. The F ratios were computed by using the within mean square as the denominator in each instance. The table shows that effect A produced a highly significant difference ($p \ll .0005$) in favor of the HOSC Instruction Method. Neither of the other principal effects nor any of the interaction effects is significant. The importance of these insignificant interaction effects is discussed in subsection 5, below.

The unadjusted and adjusted means of the class means for post-test TOUS final scores and the means of the class means for the covariance controls are shown in Table 4.3 for the significant method effect. It is clear from this table that the significant difference was in favor of the experimental group classes, which used the HOSC Instruction Method. Table 4.3 also records the differences between the means of the class means on TOUS pre-test and TOUS post-test total scores for the experimental and control classes. We note that the control group classes also made significant gains in TOUS total score, but they were greatly outdistanced by the experimental classes, as is indicated by the analysis of variance results.

Table 4.1

TOUS Total Analysis

Number of Classes in Each Cell

	Experimental		Control		Total
	High Rating	Low Rating	High Rating	Low Rating	
Biology	6	9	6	9	30
Chemistry	6	9	6	9	30
Physics	4	6	4	6	20
Total	40		40		80

Table 4.2

TOUS Total Analysis

Analysis of Variance Table

Source	ndf	Residual Sums of Squares	Mean Squares	F Ratio	p
HOSC Instruction Method (A)	1	170.45	170.45	102.90	<<.0005
Teacher Rating (B)	1	5.16	5.16	3.11	*
Science Course (C)	2	9.19	4.59	2.77	*
A x B Interaction	1	2.77	2.77	1.67	*
A x C Interaction	2	4.03	2.02	1.22	*
B x C Interaction	2	8.27	4.13	2.50	*
A x B x C	2	7.60	3.80	2.29	*
Within	66	109.33	1.66		
Total	77	316.80			

* = Effect not significant at .05 level

Table 4.3

TOUS Total Analysis

Results for the Method Effect

	TOUS-Post Unadjusted	TOUS-Pre	Otis	TOUS-Post Adjusted
Experimental Classes - Mean	37.10	32.01	53.78	36.76
Control Classes - Mean	33.46	31.36	52.78	33.81
All Classes - Mean	35.28	31.68	53.01	
- S. D.	5.07	4.43	7.42	
Regression Coefficients - Method Effect		.69	.20	
- Within Effect		.72	.15	

	N	Difference between TOUS-Post and TOUS-Pre ↓	t	p
Experimental Classes	40	+ 5.09	15.24	<<.001
Control Classes	40	+ 2.10	6.28	<.001

Table 4.4 gives the observed cell means and principal effects means for TOUS post-test (unadjusted), TOUS pre-test, and Otis scores; Table 4.5 gives the adjusted cell means for TOUS post-test total scores; and Table 4.6 gives the product moment correlations between the tests used.

In this analysis, we can conclude that, after taking into account initial differences in understanding and differences in scholastic aptitude, students who study under the HOSC Instruction Method attain a significantly greater understanding of science and scientists, as measured by TOUS total scores, than students who do not.

Table 4.4

TOUS Total Analysis

Observed Cell Means and Principal Effects Means

		Experimental		Control		Means for Science Course Effect
		High Rating	Low Rating	High Rating	Low Rating	
Biology	TOUS-Post	35.61	32.58	28.01	31.71	32.01
	TOUS-Pre	30.92	28.00	27.20	29.63	28.91
	Otis	49.87	46.76	44.56	50.32	48.01
Chemistry	TOUS-Post	41.50	36.61	33.97	34.00	36.28
	TOUS-Pre	35.04	31.68	32.78	31.69	32.37
	Otis	58.95	54.09	51.89	54.08	54.61
Physics	TOUS-Post	39.37	40.23	39.52	36.18	38.70
	TOUS-Pre	34.05	35.20	35.88	34.16	34.80
	Otis	57.42	60.17	58.17	56.48	58.11
Means for Method Effect	TOUS-Post	37.10		33.46		
	TOUS-Pre	32.01		31.36		
	Otis	53.78		52.25		
		High		Low		
Means for Teacher Rating Effect	TOUS-Post	35.94		34.84		
	TOUS-Pre	32.17		31.36		
	Otis	52.94		53.06		
Grand Means	TOUS-Post	35.28		S.D.	TOUS-Pre	5.07
	TOUS-Pre	31.68			TOUS-Post	4.43
	Otis	53.01			Otis	7.42

Table 4.5

TOUS Total Analysis

Adjusted Cell Means for TOUS Post-Test

	Experimental		Control		Total for Course
	High Rating	Low Rating	High Rating	Low Rating	
Biology	36.63	36.17	32.51	33.59	34.76
Chemistry	38.19	36.45	34.07	33.83	35.54
Physics	37.00	36.61	35.72	33.87	35.69
Total for Method	36.76		33.81		
Total High Rating	35.60				
Total Low Rating	35.07				

Table 4.6

TOUS Total Analysis

Correlations Between Tests

	TOUS-Pre	OTIS
TOUS-Post	.91	.87
TOUS-Pre		.89

2. TOUS Scale 1 Analysis[1]

Scale 1 of TOUS measures a student's understanding of "The Scientific Enterprise" (--see chapter III, page 44--). In this analysis, the criterion variable, Y_{stu}, is the class mean of the post-test TOUS scale 1 scores. The first covariance control, X_1, is the class mean of the pre-test TOUS scale 1 scores. The two levels of effect B were obtained by dichotomizing the teacher's area 1 scale ratings (--see Table 3.12--), so that "low" corresponded to scale ratings from 0 to 5 and "high" corresponded to scale ratings from 5 to 9.[2]

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[1] The analysis of the TOUS total score, reported in subsection 1, demonstrated the superiority of the HOSC Instruction Method in teaching for the science objectives measured by TOUS. Strictly speaking, the following TOUS scale analyses (subsections 2, 3, and 4) are descriptive of where these differences tend to lie and are not necessarily tests of inference. This is because the type of "pyramid" hypothesis testing conducted here affects the probability levels. Nevertheless, we feel that these further explorations are important in order to identify more specifically the ways in which the HOSC Instruction Method was relatively successful or unsuccessful.

[2] The reader may have noted that the point used for dividing the teacher's area 1 scale ratings is different from the point used for dividing the teacher's total scale ratings in subsection 1. Similarly, differences in the dividing points will also be seen for teacher's area II scale ratings and teacher's area III scale ratings. The reason for the differences is that, in each instance, the point which maximized the number of classes to be included in the analysis was selected for the dichotomization of the scale ratings. For this reason also, and because the teacher ratings ("high" or "low") were based upon the teachers' performances in the several areas, the number of classes in each cell for the total analysis and for the three scale analyses varies (--see Tables 4.1, 4.7, 4.10, and 4.13--). The ratio of classes in the "high"-"low" dichotomy was changed slightly for each analysis, but the desired aim of always including a maximum number of classes was realized.

With the number of classes that fell in each cell and the restriction of proportionality, the maximum possible number of classes that could be included in this analysis was 80. The following ratios among cells were used:

(A) experimental : control = 1 : 1

(B) high rating : low rating = 1 : 1

(C) biology : chemistry : physics = 7 : 8 : 5

The classes to be included in the analysis were randomly selected, where necessary, for each cell. Table 4.7 gives the number of classes in each cell for this analysis.

Table 4.8 is the analysis of variance table for the TOUS scale 1 score. The F ratios were computed by using the within mean square in each instance. The table shows that effect A, HOSC Instruction Method, produced a highly significant difference ($p < .0005$). Neither of the other principal effects nor any interaction effects is significant.

The unadjusted and adjusted means for post-test TOUS scale 1 scores and the means for the covariance controls are shown in Table 4.9 for the significant method effect. The significant difference on TOUS scale 1 is clearly in favor of the experimental group classes, which used the HOSC Instruction Method. This table also shows that the control group classes, as well as the experimental group classes, made significant gains in TOUS scale 1 scores from pre-test to post-test. However, the analysis of variance results clearly demonstrate that the gains of the experimental classes were much greater than the gains of the control classes.

In this analysis, we can conclude that, after initial differences in understanding and differences in scholastic aptitude are taken into account, students who study under the HOSC Instruction Method attain a significantly greater understanding of the scientific enterprise, as measured by TOUS scale 1 scores, than students who do not.

Table 4.7

TOUS Scale 1 Analysis

Number of Classes in Each Cell

	Experimental		Control		Total
	High Rating	Low Rating	High Rating	Low Rating	
Biology	7	7	7	7	28
Chemistry	8	8	8	8	32
Physics	5	5	5	5	20
Total	40		40		80

Table 4.8

TOUS Scale 1 Analysis

Analysis of Variance Table

Source	ndf	Residual Sums of Squares	Mean Squares	F Ratio	p
HOSC Instruction Method (A)	1	35.93	35.93	97.92	<.0005
Teacher Rating (B)	1	0.01	0.01	0.03	*
Science Course (C)	2	0.97	0.48	1.32	*
A x B Interaction	1	0.15	0.15	0.42	*
A x C Interaction	2	0.56	0.28	0.76	*
B x C Interaction	2	0.59	0.30	0.81	*
A x B x C	2	0.06	0.03	0.09	*
Within	66	24.22	0.37		
Total	77	62.49			

* = Effect not significant at .05 level

Table 4.9

TOUS Scale 1 Analysis

Results for the Method Effect

	TOUS-Post Unadjusted	TOUS-Pre	Otis	TOUS-Post Adjusted
Experimental Classes - Mean	12.08	9.98	53.47	11.99
Control Classes - Mean	10.55	9.85	52.33	10.64
All Classes - Mean	11.31	9.91	52.85	
- S. D.	1.75	1.41	7.30	
Regression Coefficients - Method Effect		.55	.10	
- Within Effect		.59	.08	

	N	Difference between TOUS-Post and TOUS-Pre ↓	t	p
Experimental Classes	40	+ 2.10	13.73	<.001
Control Classes	40	+ 0.70	4.58	<.001

3. TOUS Scale 2 Analysis

Scale 2 of TOUS measures a student's understanding of "Scientists". In this analysis, the criterion variable, Y_{stu}, is the class mean of the post-test TOUS scale 2 scores. The first covariance control, X_1, is the class mean of the pre-test TOUS scale 2 scores. The two levels of effect B were obtained by dichotomizing the teacher's area II scale ratings (--see Table 3.13--), so that "low" corresponded to scale ratings from 0 to 3 and "high" corresponded to scale ratings from 4 to 9.

With the number of classes that fell in each cell and the restriction of proportionality, the maximum possible number of classes that could be included in this analysis was 72. The following ratios among cells were used:

(A) experimental : control = 1 : 1
(B) high rating : low rating = 5 : 4
(C) biology : chemistry : physics = 1 : 2 : 1

The classes to be included in the analysis were randomly selected, where necessary, for each cell. Table 4.10 gives the number of classes in each cell for this analysis.

Table 4.11 is the analysis of variance table for the TOUS scale 2 score. The F ratios were computed by using the within mean square as the denominator in each instance. The table shows that effect A, HOSC Instruction Method, produced a significant difference ($p <.05$). Neither of the other principal effects nor any interaction effects is significant.

The unadjusted and adjusted means for post-test TOUS scale 2 scores and the means for the covariance controls are shown in Table 4.12 for the significant method effect. The significant difference on TOUS scale 2 is clearly in favor of the experimental group classes, which used the HOSC Instruction Method. The t-tests reported in this table also show that the control goup classes, as well as the experimental group classes, made significant gains in TOUS scale 2 scores from pre-test to post-test. Although the analysis of variance results indicate that the gains of the experimental classes were greater than the gains of the control classes, the difference here is not so great as in the other TOUS scales. Indeed, the adjusted means of the TOUS post-test for scale 2 show a relatively small (0.36 point) difference between the experimental classes and the control classes.

In this analysis, we can conclude that, after intial differences in understanding and differences in scholastic aptitude are taken into account, students who study under the HOSC Instruction Method attain a significantly greater understanding of scientists, as measured by TOUS scale 2 scores, than students who do not.

Table 4.10

TOUS Scale 2 Analysis

Number of Classes in Each Cell

	Experimental		Control		Total
	High Rating	Low Rating	High Rating	Low Rating	
Biology	5	4	5	4	18
Chemistry	10	8	10	8	36
Physics	5	4	5	4	18
Total	36		36		72

Table 4.11

TOUS Scale 2 Analysis

Analysis of Variance Table

Source	ndf	Residual Sums of Squares	Mean Squares	F Ratio	p
HOSC Instruction Method (A)	1	2.27	2.27	6.76	<.05
Teacher Rating (B)	1	0.02	0.02	0.07	*
Science Course (C)	2	1.00	0.50	1.49	*
A x B Interaction	1	0.20	0.20	0.59	*
A x C Interaction	2	0.32	0.16	0.48	*
B x C Interaction	2	0.89	0.44	1.32	*
A x B x C	2	0.30	0.15	0.44	*
Within	58	19.48	0.34		
Total	69	24.48			

* = Effect not significant at .05 level

Table 4.12

TOUS Scale 2 Analysis

Results for the Method Effect

	TOUS-Post Unadjusted	TOUS-Pre	Otis	TOUS-Post Adjusted
Experimental Classes - Mean	12.05	11.05	54.12	11.96
Control Classes - Mean	11.51	10.83	52.66	11.60
All Classes - Mean	11.78	10.94	53.39	
- S. D.	1.21	1.27	7.03	
Regression Coefficients				
- Method Effect		.64	.03	
- Within Effect		.64	.02	

		Difference between TOUS-Post and TOUS-Pre		
	N	↓	t	p
Experimental Classes	36	+ 1.00	9.35	$< .001$
Control Classes	36	+ 0.68	6.36	$< .001$

4. TOUS Scale 3 Analysis

Scale 3 of TOUS measures a student's understanding of the "Methods and Aims of Science". In this analysis, the criterion variable, Y_{stu}, is the class mean of the post-test TOUS scale 3 scores. The first covariance control, X_1, is the class mean of the pre-test TOUS scale 3 scores. The two levels of effect B were obtained by dichotomizing the teacher's area III scale ratings (--see Table 3.14--), so that "low" corresponded to scale ratings from 0 to 4 and "high" corresponded to scale ratings from 4 to 9.

With the number of classes that fell in each cell and the restriction of proportionality, the maximum possible number of classes that could be included in this analysis was 78. The following ratios among cells were used:

(A) experimental : control = 1 : 1

(B) high rating : low rating = 1 : 2

(C) biology : chemistry : physics = 5 : 5 : 3

The classes to be included in the analysis were randomly selected, where necessary, for each cell. Table 4.13 gives the number of classes in each cell for this analysis.

Table 4.14 is the analysis of variance table for the TOUS scale 3 score. The F ratios were computed by using the within mean square as the denominator in each instance. The table shows that effect A, HOSC Instruction Method, produced a significant difference ($p < .0005$). Neither of the other principal effects nor any interaction effects is significant.

The unadjusted and adjusted means for post-test TOUS scale 3 scores and the means for the covariance controls are shown in Table 4.15 for the significant method effect. The significant difference on TOUS scale 3 is clearly in favor of the experimental group classes, which used the HOSC Instruction Method. This table also shows that the control group classes, as well as the experimental group classes, made significant gains in TOUS scale 3 scores from pre-test to post-test. However, as revealed by the analysis of variance, the gains of the experimental classes were much greater than the gains of the control classes.

In this analysis, we can conclude that, after initial differences in understanding and differences in scholastic aptitude are taken into account, students who study under the HOSC Instruction Method attain a significantly greater understanding of the methods and aims of science, as measured by TOUS scale 3 scores, than students who do not.

Table 4.13

TOUS Scale 3 Analysis

Number of Classes in Each Cell

	Experimental		Control		Total
	High Rating	Low Rating	High Rating	Low Rating	
Biology	5	10	5	10	30
Chemistry	5	10	5	10	30
Physics	3	6	3	6	18
Total	39		39		78

Table 4.14

TOUS Scale 3 Analysis

Analysis of Variance Table

Source	ndf	Residual Sums of Squares	Mean Squares	F Ratio	p
HOSC Instruction Method (A)	1	14.92	14.92	27.83	<.0005
Teacher Rating (B)	1	0.39	0.39	0.72	*
Science Course (C)	2	1.65	0.83	1.54	*
A x B Interaction	1	1.03	1.03	1.92	*
A x C Interaction	2	1.86	0.93	1.74	*
B x C Interaction	2	0.12	0.06	0.11	*
A x B x C	2	0.31	0.16	0.29	*
Within	64	34.32	0.54		
Total	75	54.60			

* = Effect not significant at .05 level

Table 4.15

TOUS Scale 3 Analysis

Results for the Method Effect

	TOUS-Post Unadjusted	TOUS-Pre	Otis	TOUS-Post Adjusted
Experimental Classes - Mean	12.57	10.77	52.51	12.53
Control Classes - Mean	11.62	10.70	52.28	11.66
All Classes - Mean	12.09	10.73	52.40	
- S. D.	2.04	1.79	6.96	
Regression Coefficients - Method Effect		.74	.08	
- Within Effect		.73	.08	

	N	Difference between TOUS-Post and TOUS-Pre ↓	t	p
Experimental Classes	39	+ 1.80	12.33	<.001
Control Classes	39	+ 0.92	6.30	<.001

5. Summary of Main Analyses

The foregoing analyses allow us to reject the primary null hypothesis with great confidence. The analyses show that there are indeed significant differences in understanding of science and scientists between students who have studied under the HOSC Instruction Method, as used in this Project, and those who have not. The students in classes which used the HOSC Instruction Method showed much greater gains on TOUS than the students in the control group classes; for TOUS total score, TOUS scale 1 score, and TOUS scale 3 score well beyond the .0005 level of significance, and for TOUS scale 2 score beyond the .05 level of significance. We interpret this to mean that, to the extent that TOUS is a valid measure of these areas of understanding, the HOSC Instruction Method is more effective in achieving gains in student understanding of the "Scientific Enterprise" and the "Methods and Aims of Science" than in achieving gains in student understanding of "Scientists".

We have already noted that in all of the main analyses none of the variation in the criterion measure could be attributed to any controlled sources other than the method effect. Hence, the following interpretations apply equally to the TOUS total analysis and to each of the TOUS scale analyses.

Effect B, the teacher's initial understanding (as rated in the Project), is not a significant source of variation. This result is rather surprising. It suggests that, when differences in initial student understanding and general scholastic aptitude are taken into account, students can be expected to perform equally well on post-test TOUS irregardless of whether a teacher is rated "high" or "low" on his initial understanding. (This finding is further clarified below in the discussion of interaction effects).

Effect C, the type of science course, is also not a signficant source of variation. This indicates that students in classes in biology, in chemistry, and in physics can be expected to perform equally well on post-test TOUS, when differences in pre-test TOUS performance and their general scholastic aptitude have been allowed for.

There is no significant interaction between the instruction method used, i.e., experimental or control treatment, (effect A), and the teacher's initial understanding of science and scientists (effect B). This means that the relative effectiveness of the HOSC Instruction Method, in teaching TOUS-type understandings does not depend upon whether the teacher rates "high" or "low" in his initial understanding. It appears that a teacher who rates "high" in initial understanding does not have an advantage in using the HOSC Instruction Method effectively over a teacher who rates "low" in initial understanding, or vice-versa. For the control group, the absence of significant interaction between effects A and B is more difficult to fathom, since we might expect that a teacher rated "high" in initial understanding would be more likely to produce greater gains in his students' understanding than a teacher rated "low". The absence of significant interaction here can probably be taken to mean that, under the generally employed instruction methods, the kinds of understandings measured by TOUS are not emphasized sufficiently to make much difference in how well the teacher understands them.

There is no significant interaction between instruction method used (effect A) and type of science course (effect C). This means that students studying under the HOSC Instruction Method can be expected to make similar relative gains over the control groups, as measured by TOUS, whether they are taking a course in biology, in chemistry, or in physics. Therefore, students as young as high school sophomores (the primary biology age group) seem to profit from the HOSC Instruction Method.

There is no significant interaction between teacher's initial understanding of science and scientists (effect B) and type of science course (effect C). This means that student success on TOUS does not depend upon particular combinations "high" or "low" rated teachers and whether the class is biology, chemistry, or physics.

There is no significant interaction among effects A, B, and C. This means that the greater gains in understanding achieved by students studying under the HOSC Instruction Method do not depend upon particular combinations of teacher's rating in initial understanding and of the type of science course in which the students are enrolled.

In summary, then, the findings of the main analyses allow us to state that, both for TOUS total score and for any of the TOUS scale scores, the greater gains in understanding made by students depend on whether or not they studied under the HOSC Instruction Method, and do not depend upon the other principal effects, or combinations of the other principal effects which were considered in this experiment.

B. SUBJECT TEST ANALYSES

In this series of analyses, the null hypothesis under test was:

> There are no significant differences in achievement in the usual science content of the course between students who have studied under the HOSC Instruction Method as part of their regular science class work and students who have not.

Since three different criterion instruments, Cooperative Biology Test, Cooperative Chemistry Test, and Cooperative Physics Test, were used for the corresponding science subject classes, it was necessary to carry out three separate analyses.

Each of the three analyses employed a one-way analysis of variance design with covariance adjustment. The criterion measure in each analysis was the class mean of the Cooperative Test scale scores. The class mean of the Otis Mental Ability Test raw scores was the covariance control.

For our analyses of this series, we used a computer program that computes the value of Wilks's lambda (Λ) for the general analysis of variance with covariance adjustment.[1] Wilks's lambda is simply a generalization of the univariate analysis of variance, and Rao presents the following conversion to the F distribution:

$$F^{2r}_{ms+2\lambda} = \left(\frac{1-\Lambda^{1/s}}{\Lambda^{1/s}}\right)\left(\frac{ms+2\lambda}{2r}\right)$$

where Λ = Wilks's lambda, and r, m, s, and λ are constants determined by the number of experimental and control variables, the number of groups, and the number of cases (N) in the analysis. In our three analyses, the values of these constants were

$r = .5$

$s = 1$

$m = N - 3.5$ Thus, $2r = 1$

$\lambda = -.25$ $ms + 2\lambda = N - 4$

The value of N is different for each analysis, but the other values remain the same in the calculations of F for the three analyses.

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[1] For a discussion of Wilks's lambda, see C.R. Rao, Advanced Statistical Methods in Biometric Research, (New York: John Wiley, 1952), pages 258-272. The computer program used is presented in W.W. Cooley and P.R. Lohnes, Procedures for Multivariate Analysis in the Behavioral Sciences, (New York: John Wiley, 1962), chapter 4. -- This method of analysis was used here because the computer program used in the main analyses above could handle only two- or three-way designs, and the subject test analyses were all one-way designs.

The sample used in the subject test analyses included 101 of the original 108 classes participating in the experiment. It was necessary to delete the other seven classes from the subject test analyses either because the data for the class were not complete (5 classes) or because an experimental group teacher had taught only one HOSC Instruction Method unit.[1] The following participating classes were included in the subject test analyses:

Biology -	Experimental	18 of original	19 classes
	Control	20 of original	22 classes
Chemistry -	Experimental	18 of original	19 classes
	Control	20 of original	20 classes
Physics -	Experimental	13 of original	15 classes
	Control	12 of original	13 classes
		101	108

In the following four subsections, we present the results of the subject test analyses and a summary of these findings.

1. Biology Classes Analysis

The experimental and control group means and standard deviations of the class means for the Cooperative Biology Test scale scores and for the Otis Mental Ability Test raw scores are shown in Table 4.16 . The computed value of Wilks's lambda is

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[1] The classes deleted from the subject test analyses were the same ones that were deleted from the main analyses (--see page 85, above--), with one exception. One biology, experimental class (code 151), which was deleted from the main analyses, was included in the subject test analyses.

0.862, from which we calculate $F = 5.44$. With 1 and 34 degrees of freedom, this F is significant at the .05 level. The significant difference is in favor of the control group.

The biology control group classes were slightly superior to the biology experimental group classes in general scholastic aptitude, but this was allowed for by covariance adjustment of the Coop Biology scores. In this analysis, we can conclude that, after taking into account differences in scholastic aptitude, students who do not study under the HOSC Instruction Method show more achievement in the usual content of the biology course, as measured by the Cooperative Biology Test, than students who do.

2. Chemistry Classes Analysis

The experimental and control group means and standard deviations of the class means for the Cooperative Chemistry Test scale scores and for the Otis Mental Ability Test raw scores are shown in Table 4.17 . The computed value of Wilks's lambda is 0.998, from which we calculate $F = .085$. This F is not significant.

In this analysis, we can conclude that, after taking into account differences in scholastic aptitude, students who study under the HOSC Instruction Method show the same achievement in the usual content of the chemistry course, as measured by the Cooperative Chemistry Test, as students who do not.

Table 4.16

Biology Test Analysis

	N	Coop Biology		Otis Score	
		Mean	S.D.	Mean	S.D.
Experimental	18	56.51	6.13	46.61	7.78
Control	20	58.95	6.38	46.92	6.04
Total	38	57.80	6.38	46.77	7.86

$\Lambda = 0.862$ $F^1_{34} = 5.44$ $.05 > p > .01$

Table 4.17

Chemistry Test Analysis

	N	COOP Chemistry		Otis Score	
		Mean	S.D.	Mean	S.D.
Experimental	18	63.58	6.21	56.15	5.97
Control	20	61.28	5.61	52.61	6.07
Total	38	62.37	6.01	54.29	6.27

$\Lambda = 0.998$ $F^1_{34} = .085$ $p > .05$
(Not significant)

3. Physics Classes Analysis.

The experimental and control group means and standard deviations of the class means for the Cooperative Physics Test scale scores and for the Otis Mental Ability Test raw scores are shown in Table 4.18 . The computed value of Wilks's lambda is 0.970, from which we calculate F = .649 . This F is not significant.

In this analysis, we can conclude that, after taking into account differences in scholastic aptitude, students who study under the HOSC Instruction Method show the same achievement in the usual content of the physics course, as measured by the Cooperative Physics Test, as students who do not.

4. Summary of Subject Test Analyses

The foregoing analyses allow us to reject the null hypothesis for the biology classes, but not for the chemistry and physics classes. In chemistry and physics, the analyses show that there are no significant differences in achievement in the usual science content of the course between students who have studied under the HOSC Instruction Method and students who have not. In biology, there are significant differences in favor of students who have not studied under the HOSC Instruction Method. Thus, it appears that students in biology classes which used the HOSC Instruction Method were deficient in their achievement in the usual content of the biology course, to the extent that it is measured by the Cooperative Biology Test, in comparison with students who did not use HOSC.

Table 4.18

Physics Test Analysis

	N	Coop Physics		Otis Score	
		Mean	S.D.	Mean	S.D.
Experimental	13	58.25	7.10	57.71	5.81
Control	12	58.94	3.17	57.25	2.56
Total	25	58.58	5.58	57.49	4.56
$\Lambda = 0.970$	$F^1_{21} = .649$	$p > .05$ (Not significant)			

It may be argued that, since the students in biology classes using the HOSC Instruction Method made significantly greater gains in their understanding of science and scientists than students in biology classes which did not, their poorer showing in the usual content of the biology course (on the average, a difference of approximately two questions on the Cooperative Biology Test) has been more than adequately compensated.

In the case of students in chemistry and physics classes, the argument is different. The students in these classes which used the HOSC Instruction Method made significantly greater gain in their understanding of science and scientists than students in chemistry and physics classes which did not, without concomitant significant differences in achievement in the usual science content of the course. This finding should go a long way toward vitiating the objection to the use of the HOSC units on the grounds that the time thus spent is detrimental to attaining sufficient coverage of the usual science subject matter of the course. We find that students who have studied in chemistry or physics classes where two HOSC units were included, (requiring a total of approximately four weeks of class time) can be expected to perform as well on standardized chemistry or physics achievement tests[1] as students who studied in classes where the HOSC units were not used.

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[1] We believe this finding also applies to the Achievement Tests of the College Entrance Examination Board as they are now constituted.

Our motivation for carrying out the subject test analyses was to explore question of what loss there might be in student achievement in the usual content of biology, chemistry, and physics courses if the use of the HOSC Instruction Method, no matter what its virtues may be, is advocated. Our answer, based on the analyses, is that in biology there is some loss in student achievement, which is probably not serious, and that in chemistry and physics, little or nothing in student achievment is lost.

C. OTHER FINDINGS

In the remainder of this chapter, we shall give summaries of other findings, which did not lend themselves to rigorous statistical analysis. Specifically, the following two subsections discuss the responses of the experimental group teachers to Questionnaire Number 3 and the data obtained from "Experimental Group B" classes.

1. Questionnaire Number 3 Responses

> "Interestingly enough, some of the students who are more literarily than scientifically inclined did much better on HOSC than on the regular chemistry traditional approach. 'This is the first time we've understood what labs are all about,' said a couple of these students.
>
> "The strength of the program is the performance of these experiments under conditions and limitations similar to those facing the original discoverers. This touch with the historical past is something which never happens in a standard chemistry course.

> "The program is good. It seems to contradict something which Conant says in his book, that he thinks this approach won't work below the college level. I'm sure, even though the teaching was far from perfect, the students got an idea of process and an understanding which they'd never have gotten otherwise."

Thus reads the response of an experimental group teacher to one of the leading questions on Questionnaire Number 3. This response is not atypical, for most of the teachers were well pleased with the HOSC Instruction Method, as is shown below.

Questionnaire Number 3 was designed to obtain teachers' reactions and information about the teaching of the HOSC units, as a supplement to our test data. The text of the questionnaire has been given in Chapter III (--see pages 76 and 77--). Of the 53 teachers in the experimental group, 47 (or 89%) returned completed questionnaires. Half of the questions asked on the questionnaire called for responses concerning details of particular units or about the teaching kit materials, and it would not be too profitable to summarize these responses here. However, for the remaining questions, it was possible to classify the responses and, thereby, to discern some meaningful trends.

In answer to the leading question, "Did you like or dislike teaching by the HOSC Instruction Method?" (item 11, see Table 4.19), 62% of the teachers replying gave a definitely positive response. From among these, we could select, a number of laudatory statements, but we shall content ourselves with one example, written by a physics teacher:

Table 4.19

Responses to Item 11 of Questionnaire Number 3

Question:

"Did you like or dislike teaching by the HOSC Instruction Method?"

	Biology	Chemistry	Physics	Total	
Positive Response	10	12	7	29	(62%)
Mixed Response	3	5	3	11	(23%)
Negative Response	2	2	1	5	(11%)
No Direct Response	2	0	0	2	(4%)
Total	17	19	11	47	

> "I enjoyed teaching by the HOSC Instruction Method for several reasons:
>
> "1. We had many good class discussions and everyone, even the poorer students, participated more than in my ordinary class work.
>
> "2. I feel it opened the students' minds to many channels. We found ourselves discussing art, literature, music, poetry and philosophy in connection with the Cases quite naturally; ...
>
> "3. I do feel the pupils have a better understanding of the scientist as a person and not as a 'mad' character."

Among the teachers who gave negative or mixed responses to this question, the objection most frequently stated was that the HOSC units devoted too much time to material designed to develop "attitudes", in deference to more detailed coverage of science subject matter, which the respondents held to be more important. In this connection, the strongest dissent was expressed by the one teacher who withdrew his class from participation in the Project after teaching one HOSC unit. He wrote:

> "I disliked the method, probably because I had the constant feeling that I was neglecting to teach the modern ideas and concepts of the topics for the sake of some rather nebulous principles or attitudes. ...
>
> "There probably were some benefits, but they were not sufficient to justify the time spent. Above all, if one is in the process of teaching a college preparatory course or preparing his students for College Board Examinations, this is not the approach to use; not unless or until there is a radical change in college chemistry courses and in the College Board Examinations."

When considering such responses of the teachers who were dissatisfied with the HOSC units, we can only reiterate our belief that the time used in developing the understandings about science and scientists which the HOSC Instruction Method conveys is well spent and that, as was pointed out at the beginning of this report, these understandings are extremely important in the present day.

In regard to the objection of students being penalized in their achievement in the usual content of science courses because of their study of HOSC units, we believe that the results of our subject test analyses provide a sufficient answer.

Another objection, cited particularly by biology teachers of 9th and 10th grade students, was the difficulty students had with the language, historical framework, and abstract ideas in some passages of the Cases. This objection is probably quite proper, since portions of the biology Cases may well be "over the heads" of some of the younger students. Interestingly enough, six chemistry and physics teachers commented that the material of the Cases seemed to be too easy for their students at the 11th and 12th grade levels.

In responding to "Would you use the HOSC Instruction Method as a part of your teaching in the future?" (item 13, see Table 4.20), the teachers replying to the questionnaire gave a vote of confidence to the HOSC materials. Seventy percent of the respondents said they would like to use the HOSC units, either as they now stand, with some modifications, or with advanced classes. Only 19% of the teachers said that they would not want to use the HOSC Instruction Method in the future. Not surprisingly, these teachers were generally the same ones who had expressed dissatisfaction or had experienced great difficulties with the HOSC units, as evidenced in their responses to items 11 and 12. On the whole, the response to the question of the future use of the HOSC Instruction Method was gratifying, especially when we bear in mind that almost all the teachers

3

Table 4.20

Responses to Item 13 of Questionnaire Number 3

Question:

"Would you use the HOSC Instruction Method as a part of your teaching in the future?"

	Biology	Chemistry	Physics	Total
Yes	8	14	7	29 (62%)
Yes, with advanced Classes	2	0	0	2 (4%)
Yes, with Modifications	0	0	2	2 (4%)
Perhaps, or Don't Know	2	1	1	4 (9%)
No	4	4	1	9 (19%)
No Direct Response	1	0	0	1 (2%)
Total	17	19	11	47

received their first and only exposure to these materials through their participation in the Project. There was no publicity to herald the HOSC Instruction Method; no persuasion, save the materials themselves, was employed; no in-service institutes to "orient" the teachers were held. Knowing the difficulty in gaining acceptance which innovations in education often face and recognizing the rightful individuality of science teachers, the positive vote for the future use of the HOSC materials is most encouraging.

For both the first and second HOSC units taught, the teachers were asked to give their impressions of how well the objectives for the unit, as stated in the Teacher's Guide, had been achieved (item 23, see Table 4.21; and item 33, see Table 4.22). Comparison of the responses to these two items shows that about half the teachers replying felt that all or nearly all stated objectives were achieved in both HOSC units. (Chi-square for the difference between the correlated proportions of the two tables is .0046, for which $p > .95$.) In fact, most teachers gave the same or very similar responses to items 23 and 33. Since the teachers generally had little data other than the results of the unit tests on which to base their replies to these items, we suspect that the responses quite likely are functions of the teacher's general confidence and his satisfaction with the HOSC Instruction Method, rather than realistic evaluations of the attainment of objectives.

Table 4.21

Responses to Item 23 of Questionnaire Number 3

Question:
"To what extent do you feel the Objectives for the Unit were achieved ?" (for the first HOSC unit taught)

	Biology	Chemistry	Physics	Total	
All or Nearly All Objectives Achieved	9	6	7	22	(47%)
Objectives Achieved in Part	4	8	3	15	(32%)
Objectives not well Achieved	1	2	0	3	(6%)
No Response	3	3	1	7	(15%)
Total	17	19	11	47	

Table 4.22

Responses to Item 33 of Questionnaire Number 3

Question:
"To what extent do you feel the Objectives for the Unit were achieved?" (for the second HOSC unit taught)

	Biology	Chemistry	Physics	Total	
All or nearly all Objectives Achieved	8	8	8	24	(51%)
Objectives Achieved in Part	4	6	1	11	(23%)
Objectives not well Achieved	1	1	0	2	(4%)
No Response	4	4	2	10	(21%)
Total	17	19	11	47	

In general we might expect that the second unit taught using a new method of instruction would be easier to teach than the first unit so taught. However, in response to the question, "Did this (second) unit "go" easier or harder than the first unit?" (item 34, see Table 4.23), only 57% of the teachers said that the second HOSC unit was easier to teach. Among the reasons given to support this response were that (1) the teacher gained familiarity with the new approach during the teaching of the first unit, (2) the students knew better what was expected of them after their experience with the first unit, (3) the science subject matter of the first unit was more difficult, or (4) the students already knew the answers to some questions, which were similar in the two units. For 21% of the teachers, the second HOSC unit was harder to teach than the first because (1) the science subject matter of the second unit was more difficult, (2) the students became impatient with the HOSC units and were anxious to return to the regular class work, or (3) the students were bored by the second HOSC unit, in which many questions similar to those in the first unit were asked. These replies suggest an important consideration. If a teacher plans to teach two HOSC units in one semester or in one year, the optimum scheduling would probably be to separate the two units by several weeks, at least. Unfortunately, under the circumstances of the HOSC Instruction Project, the two HOSC units were taught one right after the other in quite a number of instances.

Table 4.23

Responses to Item 34 of Questionnaire Number 3

Question:
"Did this unit 'go' easier or harder than the first one?"

	Biology	Chemistry	Physics	Total	
Easier	10	10	7	27	(57%)
About the Same	0	1	0	1	(2%)
Harder	4	4	2	10	(21%)
No Response	3	4	2	9	(19%)
Total	17	19	11	47	

Among the questions pertaining to the instructional aids that accompany the HOSC units, the most significant response was made to the question, "Were the Teacher's Guides helpful in your teaching by the HOSC Instruction Method?" (item 41, see Table 4.24). All teachers who answered this question gave an affirmative reply, with 45% saying that the Guides were very useful or essential for their teaching. Since there were no in-service sessions included in the HOSC Instruction Project, the Teacher's Guides provided the only mechanism for conveying the rationable, aims, and development of the HOSC units to the classroom teachers. Virtually no adverse criticisms of the Teacher's Guides were made, and it is gratifying to note that they were so well received.

The last question which we wish to discuss is "Do you feel that your students obtained any 'intangible' benefits, which were not measured by our tests, from their study of this unit?" (item 24, see Table 4.25). Sixty-four percent of the teachers replied affirmatively to this question. Among those teachers who were doubtful or did not respond to this question, there was some uncertainty about just what was being measured by our tests, particularly by TOUS. (Of course, the purpose of TOUS was intentionally not made explicit to the teachers during the course of the experiment.) The "intangible" benefits specified by the teachers differed widely, but the following three quotations will illustrate them. A biology teacher wrote:

> "The students obtained a new feeling for the meaning of science."

A chemistry teacher commented:

> "OF COURSE. This is the 'heart of the CASE'-- the intangibles. Nowhere have I encountered in my 35 years of teaching a better garnering of 'intangibles' and the testing of them. To mention one of the intangibles (you could hardly test for it), an appreciation for reading of science in current news --an awareness that 'all is not PAST' --a certain wonderment at the work of scientists --the feeling that scientists are really 'real people'. A feeling of being a part of a great adventure -- a personal participation. One student said, 'I have made so many new friends, Black, Hales and others.' This feeling of friendship and kinship is an intangible not tested for."

And a physics teacher wrote:

> "Discussion and opinions of class members played a larger part of classwork than normal. - Encouraged individual thinking. - Encouraged critical evaluation of science and scientists in our society today."

Another "intangible" benefit of the HOSC Instruction Method was the opportunity provided for the personal improvement of the teachers themselves. This point was explicitly noted in their Questionnaire Number 3 replies by seven teachers and was implied in the comments of several others. In this connection, one teacher wrote:

> "I believe I learned a lot about what can be done to teach certain attitudes concerning science, scientists, and the 'scientific method' as a result of the HOSC Instruction Method. The case studies helped focus my attention on these points. Now, being more aware of these objectives, I believe I can accomplish these ends throughout the whole year by integrating such objectives with my regular work."

Table 4.24

Responses to Item 41 of Questionnaire Number 3

Question:
"Were the Teacher's Guides useful in teaching the HOSC units?"

	Biology	Chemistry	Physics	Total
Essential or Very Useful	6	9	6	21 (45%)
Useful	9	9	5	23 (49%)
No Response	2	1	0	3 (6%)
Total	17	19	11	47

Table 4.25

Responses to Item 24 of Questionnaire Number 3

Question:
"Do you feel that your students obtained any 'intangible' benefits, which were not measured by our tests, from their study of this unit?"

	Biology	Chemistry	Physics	Total
Yes	11	9	10	30 (64%)
Doubtful or Don't Know	1	3	0	4 (9%)
No	0	2	0	2 (4%)
No Response	5	5	1	11 (23%)
Total	17	19	11	47

2. "Experimental Group B"

In addition to the usual biology, chemistry, and physics classes used for the main analyses of the Project, six classes which presented special curricular or organizational situations were assigned to "Experimental Group B", from which we hoped to obtain an indication of the usefulness of the HOSC Instruction Method in such special situations (--see Chapter III, pages 33 and 34 --). Unfortunately, the data obtained from "Experimental Group B" did not provide us with as much useful information as we had anticipated. For one of the classes, the chemistry class using a team-teaching organization, post-test scores were obtained for only 12 of the original 47 students, due to reorganization of the class. The data from this class were not analyzed. For the remaining five classes, the test scores and analyses are summarized in Table 4.26.

The table shows that the students in two classes made significant gains in their understanding of science and scientists, as measured by TOUS total scores, and that the students in three classes did not make significant gains. On the basis of these results from the classes in "Experimental Group B", the only reasonable conclusion we can make is that the effectiveness of the HOSC Instruction Method in these special situations is closely related to the particular special situation of each class.

Table 4.26

Data and Analyses for "Experimental Group B"

Class Code	N		TOUS Post Total	TOUS Pre Total	Otis	Correlation between TOUS Post and TOUS Pre
931	16	Mean	27.19	27.69	44.13	.35
		S.D.	4.54	4.51	7.68	
951	13	Mean	24.85	22.46	41.38	.67
		S.D.	6.47	6.57	6.95	
969	35	Mean	38.94	33.00	49.74	.86
		S.D.	8.91	8.05	14.91	
989	24	Mean	24.75	23.67	38.42	.11
		S.D.	4.62	5.96	10.09	
991	41	Mean	30.17	27.37	43.20	.77
		S.D.	6.14	6.65	9.82	

Class Code	Difference between TOUS Post and TOUS Pre	t	p	
931	-0.50	.38	>.1	not signif.
951	+2.39	1.56	>.1	not signif.
969	+5.94	7.64	<.001	
989	+1.08	.73	>.1	not signif.
991	+2.80	4.08	<.001	

Identification of Classes:

931 - Natural Sciences, 11th and 12th grade students
New Rochelle High School, New Rochelle, N.Y.
951 - Lab Preparatory (physical science), 10th grade students
Sarasota High School, Sarasota, Fla.
969 - Science II (biology-chemistry), 10th grade students
University School, Columbus, Ohio
989 - Physical Science, 12th grade students
St. Vincent High School, Perryville, Mo. (used 1 HOSC unit)
991 - Biology, team teaching, 10th and 11th grade students
Galileo High School, San Francisco, Calif.
(originally 60 students enrolled)

This conclusion is borne out by the teachers' comments in reply to Questionnaire Number 3 and by other information concerning each class. In the biology class operating under a team teaching organization (code 991), the content of the course was not greatly different from that in biology classes organized in the usual way; studying under the HOSC Instruction Method, the students in this class gained significantly in their understanding of science and scientists, as did students in biology classes of the experimental group of the main analyses.[1] In the integrated biology-chemistry class (code 969), the teacher had previous experience with experimental use of a case history approach and the students were selected tenth graders with relatively high scholastic aptitude scores; the gain of 5.94 in TOUS total score class mean was very high in comparison with other students at this grade level.[2] In the Natural Sciences class (code 931), the Lab Preparatory class (code 951), and the Physical Science class (code 989), the teachers indicated that they felt that the HOSC units were not wholly appropriate for their respective courses and expressed doubt that the materials were suitable for their students, who were generally low in scholastic aptitude and motivation; the students in these classes did not achieve significant gains in their understanding of science and scientists through studying under the HOSC Instruction Method.

---

[1] The gain of 2.80 in TOUS total score mean for class 991 may be compared with the corresponding gain for biology classes in the experimental group and in the control group. For biology experimental classes, the mean of the differences between pre-test TOUS total score means was + 4.62; for the biology control classes, this value was + 1.57.

[2] As a result of the experience in the HOSC Instruction Project, one of the HOSC units, in modified form, has been incorporated into the curriculum of this integrated course at University School, Columbus, Ohio. See Irwin L. Slesnick and Victor Showalter, "Program Development in Unified Science," The Science Teacher, Vol. 28, No. 8, (Dec. 1961), pages 54-55.

(Parenthetically, we note in Table 4.26 that the correlations between TOUS pre-test scores and TOUS post-test scores are very low for two of the last three classes mentioned. For all students in the main analyses, the correlation between pre-test TOUS total scores and post-test TOUS total scores, when computed from individual student scores,[1] was found to be 0.75 . The correlations of 0.35 between pre-test TOUS and post-test TOUS for class 931 and of 0.11 for class 989 throw some doubt on the confidence we can have in the data collected from these two classes.)

In general the comments of the teachers of the six classes in "Experimental Group B" were more critical than complimentary. In answer to the question, "Did you like or dislike teaching by the HOSC Instruction Method?" (item 11), one teacher gave a positive response, the teachers of three classes gave mixed responses, and the teachers of two classes gave negative responses. A similar pattern of replies obtained in answer to the question, "Would you use the HOSC Instruction Method as a part of your teaching in the future?" (item 13), to which the response of one teacher was classified as positive, the responses of teachers of three classes were classified as "perhaps," and the responses of teachers of two classes were classified as negative. All but one of the teachers felt that the HOSC materials were not appropriate for the particular course in which they had been tried, but four teachers felt that they could be used in other circumstances. The following quotation represents this view:

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[1] This value is necessarily lower than the correlation of 0.91 which was computed from class means and is reported in Table 4.6 .

> "I would use this material with our non-science majors as a portion of the overall effort to bring about attitudes toward the study of science which would be supportive and positive."

In summary, then, our sampling of classes which present special curricular or organizational situations reveals that due caution must be exercised before the HOSC Instruction Method is recommended for use in a particular instance. This finding can hardly be heralded as an idea which was not previously known to educators in regard to any instructional innovation. Yet, it seems worthwhile to have this fact emphasized once again, for it is all too common to hear an instructional innovation boldly recommended when the basis for the recommendation is a small, and often non-representative, sample of the population of potential users.

Seen in this light, our findings from the six classes in "Experimental Group B" take on less importance. Our judgment on the effectiveness of the HOSC Instruction Method rests primarily on the broad base of the sample of classes of the main analyses.

Chapter V. Conclusions and Implications

The conclusions from our several analyses have already been given in their relevant places among the findings presented in the preceding chapter. In this chapter, we summarize the major conclusions and discuss the implications partaining to the primary problem of this study: the effectiveness of the HOSC Instruction Method in increasing student understanding of science and scientists.

A. VALUE OF THE HOSC INSTRUCTION METHOD

This study clearly demonstrates that the HOSC Instruction Method is definitely effective in increasing student understanding of science and scientists, when used in biology, chemistry, and physics classes in high schools. There is no significant difference in the effectiveness of the HOSC Instruction Method depending upon the type of science course in which it is used, nor is there any significant difference in effectiveness depending upon the classroom teacher's initial understanding of science and scientists. On the basis of this conclusion, we can assert that the use of the HOSC Instruction Method in high school biology, chemistry, or physics classes, which may be taught by teachers who differ in their knowledge of the ideas emphasized in the HOSC units, will increase student understanding of science and scientists.

Students in classes which used two HOSC units as a part of the science course made greater gains, of high statistical significance, in their understanding of science and scientists than students in classes where the HOSC units were not used. Students in the latter group of classes also gained in their understanding of science and scientists. This means that other teaching procedures and techniques which sicence teachers employ may also be effective in this respect. However, it is clear that, in general, the HOSC Instruction Method is far more effective than other methods in increasing student understanding of science and scientists.

In this study, and with the particular HOSC units used by the various classes, the greatest student gains were made in the areas concerned with the understandings about the scientific enterprise and with the understandings about the methods and aims of science. The least gains, though still significant, were made in the area concerning understandings about scientists. This result implies that the HOSC Instruction Method is probably less effective in increasing student understanding in the latter area. We have not yet determined the extent to which these differences in gains depend upon the characteristics of the HOSC Instruction Method or upon the characteristics of the measurement instrument employed.

During the time that a class is studying one of the HOSC units, students necessarily cover a smaller portion of the usual science content of the course than they might if they studied in some other way. However, the conclusion from our subject test analyses is that the use of the HOSC Instruction Method as a part of the science course does not seriously affect student achievement in the usual science content of the course. In chemistry and physics, students in classes which used the HOSC Instruction Method achieved as well in the usual content as students in classes which did not use any HOSC units. In biology, students in classes which did not use the HOSC Instruction Method showed better achievement in the usual content than students in classes which did, but not by a great, though statistically significant, margin. On the basis of this conclusion, we can assert that, when the HOSC Instruction Method is used, student achievement in the usual content of biology courses will be slightly lower, while student achievement in the usual content of chemistry or physics courses will not be affected.

B. IMPLICATIONS.

The results of this study have implications both for educational practice and for further research. Most importantly, we can confidently recommend the HOSC Instruction Method for use in numerous high school classes in biology, chemistry, and physics. The very favorable outcome of our analyses, coupled with the relatively large size and variety of the sample on which the analyses were based give us considerable confidence in this recommendation.

We should also point out that the HOSC Instruction Project was deliberately carried out under actual field conditions, i.e., among the varying and peculiar circumstances in schools and classrooms. The teachers who taught the HOSC units became familiar with this new instructional method amidst the pressures of other preparations and responsibilities, which are the norm for high school teaching. There were no special "orientation" sessions or in-service institutes to acquaint teachers with the HOSC Instruction Method; the only directions for using the HOSC units came from the materials themselves and from the Teacher's Guides. This is the situation that usually obtains with any instructional materials used in the schools. Because the HOSC Instruction Method was successfully used under these conditions, we believe that it can generally be used successfully in school instruction.

Nevertheless, the selection of the sample in our study enjoins us to place two restrictions on the general recommendation of the HOSC Instruction Method. In our study, the teachers who agreed to participated had all indicated that they were interested in attaining the broad objective of conveying a better understanding of science and scientists. Through this process of self-selection, no teacher who did not have an interest in attaining this broad objective participated in the study. Thus, the results of the study can justly be applied only to those teachers who consider the attainment of better student understanding of science and scientists to be an important objective of high school science instruction.

The second restriction on our general recommendation of the HOSC Instruction Method results from the selection of students for the science classes which the teachers designated for participation in the study. In the experimental group, 68% of the classes designated for participation contained primarily students who were pursuing a college-preparatory curriculum. (The breakdown by type of science course was: biology- 10 college-preparatory classes out of 19; chemistry- 15 out of 19; physics- 11 out of 15.) As a result, the bulk of our data in this study was obtained from students who were enrolled in a college-preparatory curriculum. Therefore, we can not unequivocally recommend the HOSC Instruction Method for use in science classes enrolling students from all kinds of curricula. While the generally favorable results of the study lead us to believe that the HOSC Instruction Method can be used effectively in non-college-preparatory classes as well as in classes designated "college-preparatory," further exploration of this question is necessary before a definitive statement can be made with complete confidence.

If the above two cautions are borne in mind, there appears to be no cogent reason why the HOSC Instruction Method could not be widely employed in high school science classes as a vehicle for increasing student understanding of science and scientists. Moreover, the experience of this study has shown that teachers, as well as students, derive new insights into the processes and meaning of science through the use of the HOSC Instruction Method.

This result implies that the inclusion of HOSC units, perhaps with suitable modifications, may be of considerable benefit in the training of science teachers.

Several interesting questions for further research arise from the demonstration of the overall effectiveness of the HOSC Instruction Method. The first of these questions is: what specific understandings about science and scientists are affected by study under the HOSC Instruction Method? From the three TOUS scale analyses, we already know that the use of the HOSC units was more effective in increasing student understandings about the scientific enterprise and about the methods and aims of science than in increasing understandings about scientists, as these areas of understanding are construed in the measuring instrument. However, a more detailed exploration of this question is certainly desirable. What are needed are detailed comparisons of changes on individual TOUS items from pre-test to post-test between students who studied under the HOSC Instruction Method and students who did not. These comparisons would reveal those items of understanding upon which the study of the HOSC units had a significant impact. Promising information for beginning an exploration of the question of the specific effectiveness of the HOSC Instruction Method is already available in the data obtained in the present study.

A second question for further research is: what contribution do the several components of the HOSC Instruction Method make to its effectiveness? Related to this question are considerations concerning the aspects of the HOSC units that might be improved and concerning components of the instructional method that might be deleted without loss. Although the form of the HOSC Instruction Method used in this study was evolved over a period of several years, we are not vain enough to imagine that perfection has been achieved. Variations in the content and format of the Cases and changes in the components that supplement the Cases are possible and have frequently been considered. Experiments in which modifications of the present form of the HOSC Instruction Method are employed could readily be designed. Such experiments would not need to be so elaborate as the HOSC Instruction Project, and specific modifications could be tried with only a small number of classes in each instance. Comparisons of the results from these experiments and from the present study would provide the desired insights into the relative value of the components of the HOSC Instruction Method.

A third research implication of the present study, which is more fundamental and, at the same time, more difficult to investigate, concerns the justification for the rather generalized approach of the HOSC Instruction Method. Perhaps, "shotgun approach" would be a more descriptive phrase. As the reader has no doubt noted, each of the HOSC units is designed to attain a rather lengthy list of objectives (--see chapter II, section B--). Not only are there objectives concerning items of science subject-matter and the understanding of certain science principles, but there are also objectives concerning a dozen or more understandings about science and scientists. We cannot partake of the illusion that, in one two-week unit, all of these objectives were achieved by all of the students. In fact, our realistic view is that few, if any, students achieved all the objectives. With so large a number and variety of ideas to be taught within a single unit, the sequence and structuring of the learning materials could, of necessity, not be made fully complete and detailed enough to provide reasonable assurance that any one idea would be achieved by all, or nearly all, of the students. Thus, a critic might well argue that, if the units were redesigned so as to be pinpointed toward fewer objectives, it would be possible to program the learning materials much more adequately and, thereby, assure that most of the objectives would be achieved by most of the students. Using such redesigned units, probably fewer objectives would be achieved in the same amount of class time, but, with adequate programming, most students would achieve them.

In answer to this criticism, we can justify the more generalized approach of the HOSC Instruction Method by citing two cogent points. First, we must remember that the principal purpose of the HOSC units is to increase student understanding, conceived in a broad sense, of science and scientists. Since we have no reason to believe that the attainment of any single objective, or any small group of objectives, contributes more toward this broad understanding than any other, we would like to expose students to as large a number and variety of ideas about science and scientists as possible. Second, our own and other teachers' experience with the HOSC units indicates that different students in the same class gain different ideas from their study of the same Case. Frequently, the new idea that a student obtains from his study is not one which the Case greatly emphasize, but it is nonetheless a valuable idea for broadening his understanding of science and scientists. This phenomenon of different students gaining a diversity of valuable insights from the same set of materials is much more likely to occur in a rather generalized approach than in a tightly-programmed unit. We believe that, with a similar amount of time spent, the aggregate student achievement in understanding science and scientists will be greater with the approach of the HOSC Instruction Method, even though every student does not attain the same objectives, than the aggregate student achievement with more precisely programmed materials. Clearly, further evidence is needed in support of this contention if we wish to have a firmly established justification for the approach of the HOSC Instruction Method.

Finally, we may comment on a more general implication of this study. Teaching for understandings like those which are considered in the HOSC Instruction Method have often been thought of as the "intangible" objectives of science instruction.

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Appendix A

Illustrative Materials of the HOSC Instruction Method

This appendix contains:

Covers of Cases in biology	Page	146
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Covers of Cases in chemistry		152
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Corresponding pages from Part II of the Teacher's Guide for Case 8		154 ff.
Covers of Cases in physics		157
*Pages 10 & 11 from Case 4 - FRAUNHOFER LINES		158
Corresponding pages from Part II of the Teacher's Guide for Case 4		159 ff.
"Experiments and Exercises" from the HOSC units		163 ff.
Unit Test for Case 8		167 ff.

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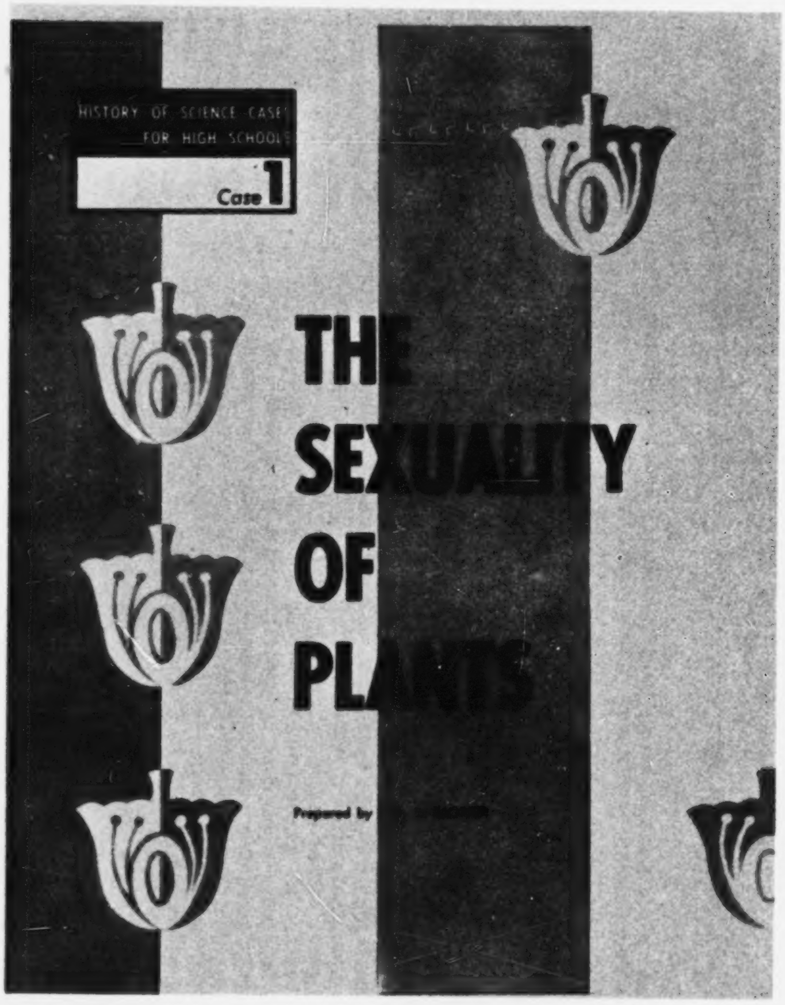
*These pages are reproduced here in reduced size. The actual page size of the Case booklets is 8½ x 11 inches.

BIOLOGY


HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 1

THE SEXUALITY OF PLANTS

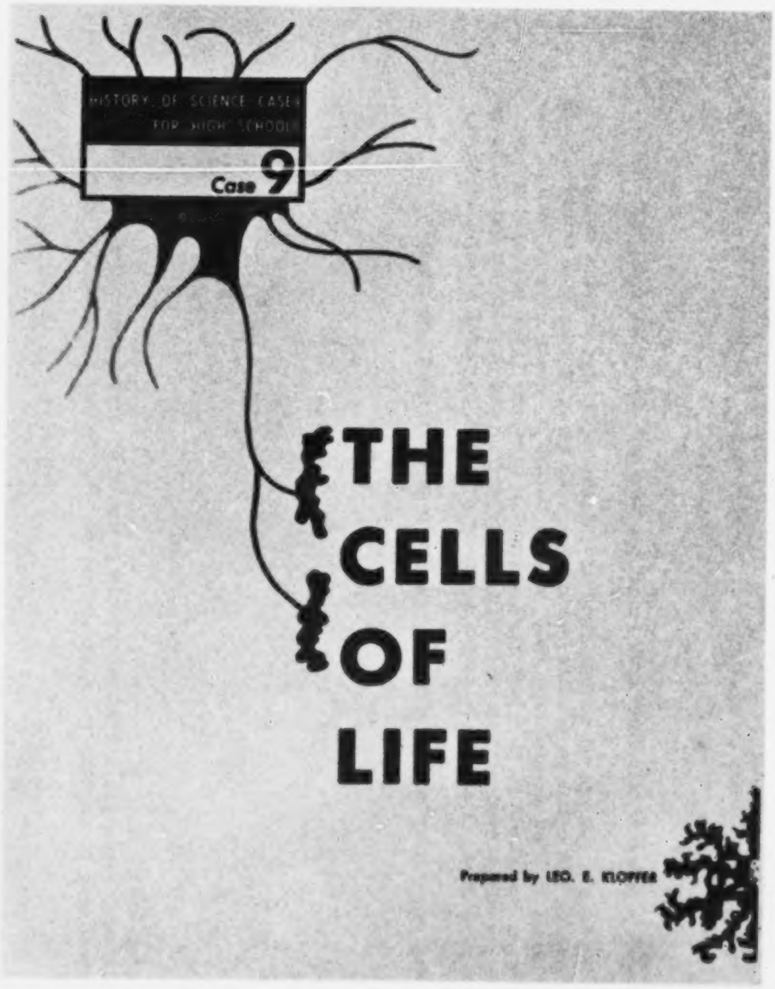
Prepared by

HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 2

FROGS AND BATTERIE

Prepared by LEO. E. KLOPFER


HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 9

THE CELLS OF LIFE

Prepared by LEO. E. KLOPFER

This experiment by Galvani is often called an "accidental discovery". What role do accidental discoveries play in science? Are most scientific discoveries made accidentally?

Where are the crural nerves located? Is there another name for them?

This is a trick question -- we've asked it this way to bring a point that you should keep in mind to your attention. Although there are crural nerves in the thigh of the frog, it is clear from Galvani's drawings (page 25) that he was referring to what we now call the "sciatic nerves". We've used Galvani's term throughout our story to be consistent, but keep in mind that the scientists in the story and the editor of the Case are referring to the sciatic nerves.

Locate the sciatic nerves on a diagram of the nervous system of the frog.

What attitudes is Galvani demonstrating? Do scientists generally have such attitudes? Do only scientists have them? Do scientists display these attitudes all the time?

What is meant by "changing the variables"?

What three variables does Galvani change? What other variables might he investigate?

not connected with the electrostatic machine, contracted every time the machine produced a spark! Here is Galvani's account of his experiment:

> I dissected a frog and prepared it. (As in Fig.∩, page 25) Having in mind other things, I placed the frog on the same table as an electrical machine, (Fig. 1) so that the animal was completely separated from and removed a considerable distance from the machine's conductor [of electric charge]. When one of my assistants by chance lightly applied the point of a scalpel to the inner crural nerves of the frog, suddenly all the muscles of the limbs were seen to contract. . . . Another assistant thought he observed that this phenomenon occurred when the spark was discharged from the conductor of the electrical machine. (Fig. 1,B) Marvelling at this, he immediately brought the unusual phenomenon to my attention. . .Hereupon I became extremely enthusiastic and eager to repeat the experiment, so as to clarify the obscure phenomenon and make it known.
>
> I myself, therefore, applied the point of the scalpel first to one then to the other crural nerve, while at the same time some one of the assistants produced a spark; the phenomenon repeated itself in precisely the same manner as before. Violent contractions [occurred] in the individual muscles of the limbs. . .at the very moment when the sparks were discharged.

This experiment is often called an "accidental discovery". - What role do accidental discoveries play in science?

Where are the crural nerves located? - Is there another name for them?

What attitudes is Galvani demonstrating here?

Galvani immediately took steps to understand this "obscure phenomenon" by changing the variables of the experiment.

What is meant by "changing the variables"?

> I was fearful, however, that these movements arose from the contact of the point, which might act as a stimulus, rather than from the spark. Consequently, I touched the same nerves again in other frogs with the point in a similar manner, and exerted even greater pressure, but absolutely no movements were seen unless someone produced a spark at the same time. Thus I formed the idea that perhaps in order to produce this phenomenon there were required the simultaneous contact of some body and the emission of a spark. I therefore again applied the edge of the scalpel to the nerves and held it motionless. I did this at one time when sparks were discharged and at another when the electrical machine was completely quiet. The phenomenon occurred, however, only as often as a spark was produced.

What three variables does Galvani change?

Observations and ideas continually interact.

Thus, Galvani found that an electric spark was necessary to obtain contractions in the muscles of the frog legs. But, what else was necessary to get the effect, and what was not needed? By diligently changing the variables in a long series of experiments, Galvani found that a scalpel touching the crural nerves of the frog was not essential. Nor was the man holding the scalpel needed. Even the electrostatic machine was not essential, for the frog legs would also contract when a spark was produced

Galvani tries to isolate the essential conditions.

Pages from Case 2 - 'FROGS AND BATTERIES'

What does Schwann mean by "logically correct"?
[As a hint, try this example. -- Almost all cars are similar in many characteristics - metal body, rubber tires, glass windows, steering wheel, and so on. Is it therefore logically correct to say that all cars are made of the same parts?]

What is an hypothesis in science?

Can you restate Schwann's two hypotheses? -- Use the form: "If . . . . then....."
[An example of this form would be: If some animal tissues have "gum-solution", then the tissues are composed of cells.]

Hypothesis 1.

Hypothesis 2.

How did Schwann come to these two hypotheses? In other words, how are Schwann's hypotheses connected with his main idea that "Cells are the basic unit of all life"? What is his reasoning? Does he make any assumptions?

How did Schwann "prove" his first hypothesis?

What is a "notochord"? Do you have one, or did you lose it?

The similarity between certain individual animal tissues with those of plants has already been mentioned. . .Nevertheless, as is logically correct, no inference has been made from such individual similarities. Every cell is not necessarily analogous in structure to some plant cell,. . .We can only draw an analogy between the cells of animal tissues with plant structures of similar elementary identity on the following grounds --

1. By demonstrating that a large part of the animal tissues originates from or consists of cells, each having its own particular wall [and a nucleus, whence] it becomes probable that such cells do correspond to the cellular elementary structure present in all plants; or
2. By proving, in connection with any particular animal tissue made up of cells, that. . .growth proceeds in them in a way similar or identical to that which occurs in plant cells.

What does Schwann mean by "logically correct"?

1. and 2. might be called Schwann's hypotheses.
What is an hypothesis?

Schwann needed considerable evidence to back up these two hypotheses. He collected the relevant observations of other workers, and, for his own study, selected the notochord of tadpoles.

How did Schwann come to these two hypotheses?

In the course of my experiments on nerve-endings in the tails of frog larvae [or tadpoles], I not only saw for myself the beautiful cellular formation of the dorsal cord in these larvae, but also discovered the nuclei in the cells. J. Muller has already proved that the dorsal cord in fishes is composed of separate cells provided with definite walls and packed closely together. . .The nuclei, so similar in form to the usual flat nuclei of plant cells, might well be mistaken for these, and thus supplied a further point of similarity. . .

What is a "notochord"?
Do you have one?

Muller had proved, in connection with the cartilage corpuscles discovered by Purkinje and Deutsch, that because of their gradual change into larger cells they must be hollow and therefore cells in the wider meaning of the term: Miescher also points out a special class of spongy cartilages of cellular structure. Similarly, nuclei were observable in the cartilage corpuscles. . .I next succeeded in actually seeing the true wall of these corpuscles, first in the branchial [or gill] cartilages of frog larvae and later also in fish, and the concordance between all of them thus proved that all cartilages possessed a cellular structure in the restricted sense of the word.

Schwann has "proved" his first hypothesis.

How did he do it?

At about this point in Schwann's investigation, Schleiden entered the picture. The two men met informally, and, as Schwann tells us, --

Scientists exchange ideas through publications and meetings and on a personal basis.

One day, when I was dining with M. Schleiden, this illustrious botanist pointed out to me the important role that the nucleus plays in the development of plant cells. I at once recalled having seen a similar organ in the cells of the notochord, and in the same instant I grasped the extreme importance that my discovery would have if I succeeded in showing that this nucleus plays the same role in the cells of the notochord as does the nucleus of plants in the development of plant cells.

(Aha!)

Pages from Case 9 - 'THE CELLS OF LIFE'

/P. 14, Q. 1/

What does Schwann mean by "logically correct"?

/ As a hint, try this example. -- Almost all cars are similar in many characteristics--metal body, rubber tires, glass windows, steering wheel, and so on. Is it therefore logically correct to say that all cars are are made of the same parts?/

*** We are not trying to create logicians with this question, but merely to point out the role that logical thinking plays in scientific work. Most of your students, especially the boys, will recognize that there is "something wrong" with the conclusion given in the example of the cars, but would they be equally critical of a similarly sloppy statement about a matter of science? -- A feeling for what is meant by "logically correct" can probably best be obtained by asking: "Just what is wrong with the statement about the cars?" ***

To generalize about a whole class of objects (--parts of all cars; all animal tissues--) on the basis of a few isolated examples (--metal body, rubber tires, etc.; "certain individual tissues"--) is logically a poor procedure. Schwann informs us that he was being cautious in not generalizing unjustifiably on the basis of the limited data available to him at first.

/P. 14, Q. 2/

What is an hypothesis in science?

An hypothesis is merely a statement of a scientist's ideas about a certain phenomenon. Usually hypothesis are based on previous experience (observations) and analysis (reasoning). Hypotheses are tested by using them to predict the outcomes of experiments, then performing the experiments and comparing the results with the predictions. ("Experiments" is here understood broadly to include the predicted observations in sciences, like astronomy, where manipulative experiments are not possible.)

An hypothesis may be concerned with a very restricted idea, such as the countless conjectures made every day in the science laboratory. On the other hand, an hypotheses may be on the grand scale, as Conant says, and may lead to a large number of predictions that can be tested by experiments. Some ready examples of this latter type of hypothesis include Copernicus's idea of the solar system, Lavoisier's ideas of the nature of combustion, Bohr's idea of the structure of the atom, Torricelli's idea of the "sea of air", Schleiden and Schwann's ideas on the cellular nature of all living things. These examples mention only grand hypotheses which were later generally accepted, but this is hardly the fate of most hypotheses which are proposed. For example, William Stokes in Science, 122: 815, (1955), recounted 29 different hypotheses proposed at various times to explain the origin of continental glaciers. All of these hypotheses were eventually rejected.

*** See GOLDSTEIN, pages 11-24. ***

/P. 14, Q. 3/ and /P. 14, Q. 4/

Can you restate Schwann's two hypotheses? --Use the form: "If... then..."
/An example of this form would be: If some animal tissues have gum-soultion", then the tissues are composed of cells./

How did Schwann come to these two hypotheses? In other words, how are Schwann's hypotheses connected with his main idea that "Cells are the basic unit of all life"? What is his reasoning? Does he make any assumptions?

*** These two questions may be conveniently treated together. They are a continuation of the discussion begun in P. 12, Q. 3. For another illustration of the process we are here discussing, see CONANT, pages 47-51. — Note that the sample hypothesis in P . 14, Q. 3 is given only to illustrate the form to be used; this was not one of Schwann's hypotheses. ***

Starting with the broad conceptual scheme (or theory) that, "Cells are the basic unit of all life,", Schwann deduced two hypotheses that could be tested by piling up observational evidence in their favor. The reasoning involved in this deduction involved two assumptions, as may be seen in the following analysis. --

CONCEPTUAL SCHEME: Cells are the basic unit of all life.

[ASSUMPTION A: All life consists of plants and animals.]

DEDUCTION: Plants and animals are composed of cells.

[ASSUMPTION B: Cells are defined (i) by their structure (i.e., cell wall plus cell nucleus)

and (ii) by their manner of growth (as given by Schleiden).]

HYPOTHESIS I. /Deduced from DEDUCTION and ASSUMPTION B (i) ./

If a sufficient number of animal tissues have nuclei and cell walls, then animal tissues are composed of cells.

HYPOTHESIS II. /Deduced from DEDUCTION and ASSUMPTION B (ii)./

If any animal tissue cells grow in the same manner as plant cells (as Schleiden described), then the tissue is composed of cells.

We can have little quarrel with the logical soundness of Schwann's reasoning, so that the testing of his two hypotheses will also serve as good tests of his conceptual scheme, providing his assumptions are correct. But are they correct?

(continued on page II - 28)

/P. 14, Q. 3/ and /P. 14, Q. 4/ (continued)

ASSUMPTION A. -- In Schwann's day, there was no reason to doubt that all life consisted of either plants or animals. However, today we know of groups of organisms that partake of both typical plant characteristics and typical animal characteristics and some that have characteristics which are not normally found in either plants or animals. Interestingly enough, it is to just such organisms that the cell theory does not seem to apply. (For further discussion of this point, see SWANSON, pages 5-7) Nevertheless, we must concede that, as far as Schwann could know, Assumption A was quite correct.

ASSUMPTION B. -- As we shall see later in this Case, the characteristics of structure and growth by which Schleiden and Schwann defined cells were shown to be inadequate, for (i), or totally incorrect, for (ii), by subsequent investigators. Perhaps the most fascinating aspect of this Case is the realization that Schwann succeeded in establishing the cell theory, probably the most important theory in biology, by using an incorrect assumption!!! Surely this does not deter us from recognizing the genius of Schwann's accomplishment in establishing his cell theory. He brilliantly employed what he considered to be the best ideas available at the time, Schleiden's definition of cells. Yet, the fact remains that Assumption B is incorrect.

/P. 14, Q. 5/

How did Schwann "prove" his first hypothesis?

Schwann "proved" his first hypothesis by the method of enumeration discussed in P. 12, Q. 3. Hypothesis I calls for "a sufficient number" of animal tissues to have nuclei and cell walls, and this leads to a series of limited working hypothese, each of which could be tested by observation. The following analysis illustrates Schwann's procedure--

HYPOTHESIS I :: If a sufficient number of animal tissues have nuclei and cell walls, then animal tissues are composed of cells.

LIMITED WORKING HYPOTHESIS I-1 : The notochord in tadpoles has nuclei and cell walls. ....TEST BY OBSERVATION.

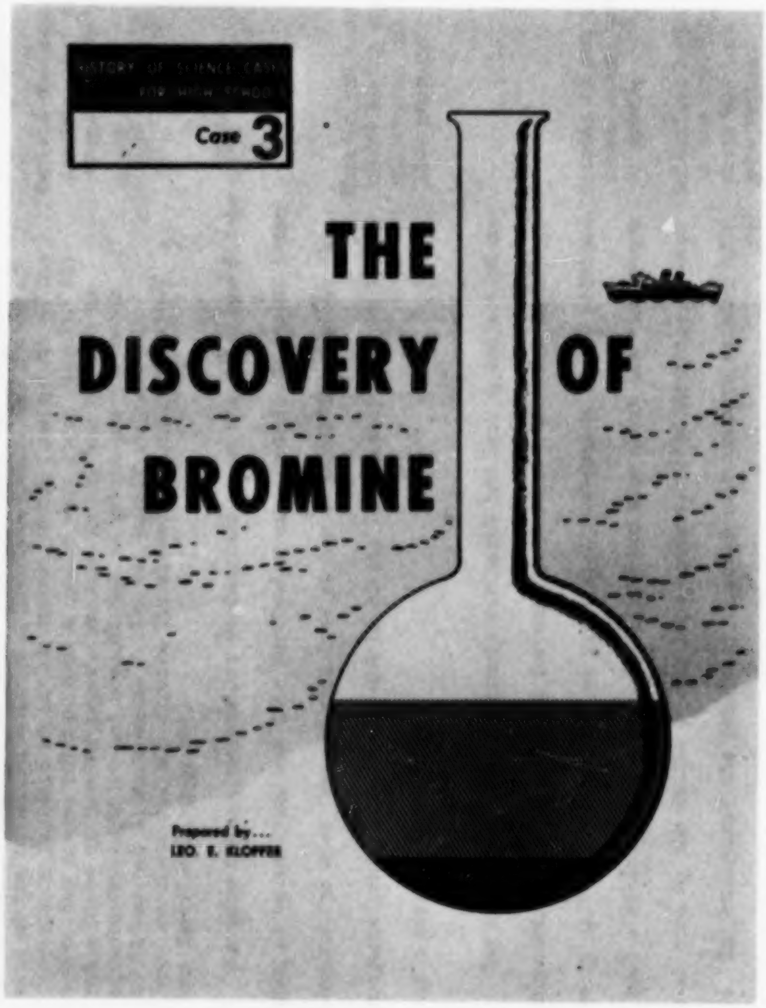
LIMITED W. H. I-2: The dorsal cord in fishes has nuclei and cell walls. ....TEST BY OBSERVATION.

LIMITED W. H. I-3: The cartilage corpuscles have nuclei and cell walls. ....TEST BY OBSERVATION.

LIMITED W. H. I-n: The ________________ has nuclei and cell walls. ....TEST BY OBSERVATION.

When Schwann found that his observations confirmed a satisfactory "sufficient number" of these limited working hypotheses, he accepted Hypothesis I. We might say that he had "proved" his first hypothesis in this way. (Recall, however, the limitation of this procedure mentioned in our comments to P. 12, Q. 3.)

CHEMISTRY

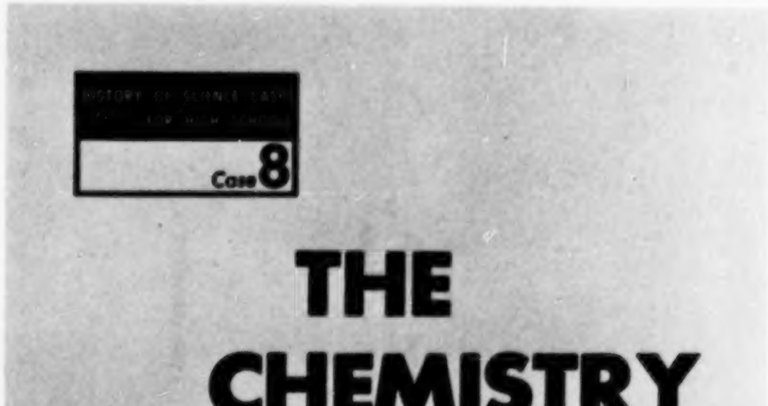


HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 3

THE DISCOVERY OF BROMINE

Prepared by...
LEO. E. KLOPFER



HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 8

THE CHEMISTRY OF FIXED AIR

Prepared by LEO. E. KLOPFER

Black forgot to write to Dr. Cullen. -- Are scientists generally absent-minded?

What do you know about living conditions in the 18th century? -- What kinds of houses did people live in? How did they heat them? What sort of manufactured goods and materials were available? What sources of power were used?

What is an element? -- Certainly, if air was considered an element, the term "element" did not mean the same as what we understand by the term "chemical element" today. What did "element" mean?

Who provides the special equipment needed for scientific work? (Incidentally, who pays for it?)

Is Hale's statement about the atmosphere a description or a concept? -- Before answering this question, you should explain what is meant by "concept." -- Is it ever possible to give a description which doesn't involve some concept? Try it.

> I fully intended to have wrote you last post, but really I happened to be intent upon something else at the proper time, and forgot it. It was, indeed, an experiment I was trying that amused me, in which I had mixed together chalk and vitriolic acid at the bottom of a large cylindrical glass; the strong effervescence produced an air or vapour, which flowing out at the top of the glass, extinguished a candle that stood close to it; and a piece of burning paper, immersed in it, was put out as effectually as if it had been dipped in water: yet the smell of it was not disagreeable." (You can easily prepare this "air" as Black did and observe its characteristic properties; see Exercise 1, page 24.)

Are scientists "absent-minded"?

Careful observations are important in scientific work.

Why were these observations so fascinating to Black and how did he happen to be carrying out this particular experiment? To answer these questions, we must take a brief look at the chemical ideas about the atmosphere prevailing in the middle of the 18th century and at Joseph Black's earlier career.

What do you know about living conditions in the 18th century?

The atmosphere that surrounds our earth had been a subject of experimentation and speculation for many centuries. Numerous investigators in different countries had given their attention to its problems, so that a sizable amount of scientific knowledge about the atmosphere was at hand by the middle of the 18th century. (See Exercise 2, page 24.) The atmosphere was generally regarded as a chaotic mixture of elementary particles of air with various impurities floating in it. Air was thought of as an element that was "permanently elastic," or as we would say, the element air always exists in a gaseous state. Stephen Hales, who perfected the apparatus which is usually used even today for studying gases, summarized the prevailing ideas in his book, Vegetable Staticks, published in 1727:

Science is not confined to any nation or group.

Scientists build on the work of those who have gone before.

What is an element?

Special equipment is needed for experimentation. Who provides it?

> Whence it is reasonable to conclude that our atmosphere is a Chaos, consisting not only of elastick [gaseous], but also of unelastick . . . particles, which in plenty float in it, as well as the sulphureous saline, watry, and earthy particles, which are no ways capable of being [changed] into a permanently elastick state, like those particles which constitute true permanent air.

Is Hales' statement about air a description or a concept?

Pages from Case 8 - 'THE CHEMISTRY OF FIXED AIR'

/P. 2, Q. 1/

Black forgot to write to Dr. Cullen. -- Are scientists generally absent-minded?

Scientists are human beings. As such, they are no more or no less likely to be absent-minded than anyone else. However, like anyone who becomes fascinated with his golf game, or an interesting conversation, or an exciting book, a scientist, intrigued by an unexpected and challenging experiment, may find time passing unnoticed and he could very well forget "to have wrote last post."

/P. 2, Q. 2/

What do you know about living conditions in the 18th century? -- What kinds of houses did people live in? How did they heat them? What sort of manufactured goods and materials were available? What sources of power were used?

*** Your students may help you in an attempt to imagine the very different conditions which prevailed in the eighteenth century. Ask them to describe frame or stone houses heated only by open fireplaces. Consider with them the goods still being handmade, since the Industrial Revolution which brought about the beginning of mass production, was still in the future when Joseph Black began his work. ***

*** In the 18th century, the scientists either had to make their own equipment or hire someone to do it for them. Where were chemicals obtained from and what means were used to purify them? How were they stored? ***

*** You may also want to consider the difficulties of communication with your students here. ***

Section Two. (18th Century Knowledge of the Atmosphere) ::

Text-- From the middle of Page 3 through middle of Page 5 to "air he obtained."
Exercise 2.

*** This section covers only a brief space in the Case, but it is important to discuss it thoroughly, so that students will be able to obtain a clear picture of the impact of Black's investigation of fixed air. What was startling in Black's work was that it contradicted generally-accepted concepts of the nature of the atmosphere. Thus, your students should have a good understanding of what these accepted concepts were. ***

*** For your own background reading on the growth of knowledge of the atmosphere, see PARTINGTON, pages 65-84 and 90-93. -- One interesting approach to this section would be to have the students dig out information on the contributions made to the 18th century knowledge of the atmosphere by the several men listed in Exercise 2. The class discussion could then be based on these reports. ***

/P. 2, Q. 3/

What is an element? --Certainly, if air was considered an element, the term "element" did not mean the same as what we understand by the term "chemical element" today. What did "element" mean?

To Black, an element seems to have meant the following:
--A substance whose properties enable us to recognize it.
--A substance whose properties are relatively invariant.
--A substance which cannot be separated into other substances.

Notice that Black's discovery of fixed air as an independent substance does not in itself prove air to be non-elemental. Even the discovery of an air-like substance, such as fixed air, but with obviously different properties could not have challenged the air-is-an-element idea even for Black, unless he believed fixed air to also be a constituent of the atmosphere.

*** You will probably want to discuss with your students the contrasts between modern definitions of an element and Black's notions. -- The historical aspects of the growth of the idea of chemical elements are quite well treated in PARTINGTON, pages 13-14, 43-44, 51-52, 70-71, and 134-135. ***

/P. 2, Q. 4/

Who provides the special equipment needed for scientific work? (Incidentally, who pays for it?)

The scientific amateurs of the past furnished their own equipment. They built it themselves or paid someone else to build it. Professors associated with universities may have had financial assistance, but again, the need for glassware, thermometers, pure substances, measuring instruments, power sources only slowly developed the technicians and industries which could stock laboratories. This situation is in sharp contrast with the highly specialized and expensive equipment in today's laboratories.

*** This question provides an instance of the dependence of scientists in doing research work upon people who are not scientists themselves. One way of treating this question might be to ask your students to discuss the effect that persons outside the science laboratory have upon the progress of research. What contributions are made by the craftsmen who build instruments, the manufacturers who supply materials and equipment, the foundation officials who approve financial grants, the university administrators who provide places to work, etc.? ***

/P. 2, Q. 5/

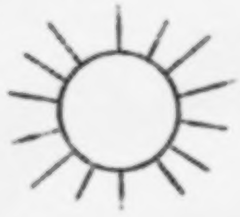
Is Hale's statement about the atmosphere a description or a concept? -- Before answering this question, you should explain what is meant by "concept". -- Is it ever possible to give a description which doesn't involve some concept. Try it.

Conant uses the word "concept" as a way of looking at or seeking to explain some phenomenon. Since a description must also reflect the describer's "way of looking at things", there must be a relationship between concepts and descriptions.

Let us consider what some concepts might be and how they could influence a description. Suppose an individual has a clear concept of roundedness as contrasted with angularity. He may always be able to distinguish a square from a circle or a rectangle from an oval. He may be able to describe these objects but if he has only the concepts of angularity and circularity his descriptions will not distinguish the oval form from the circle or the square from the rectangle. Only new concepts which relate the different parts of the given figures permit a description which will adequately distinguish them.

Other examples: to describe the sun moving across the sky, concepts of motion, foreground-background, and predictable change of position become necessary; to describe a mountain, concepts of levelness and breaks in levelness, size relative to ordinary objects and adjustments in viewing positions can present possibilities for descriptions which could vary.

With this "feeling" for the notions of concept, let us consider whether it is ever possible to describe without some concepts. Even the most objective description must rely on some agreed verbal name or some kind of symbol or sign to represent a concept. A circle with divergent rays → is not the sun but a large proportion of peoples, including extreme primitives, would recognize the symbol. Concepts of circularity and radiation are clearly indicated. Another group of people could agree on a much more arbitrary symbol such as a square or triangle or even three separate little scrawls such as S U N .



Note that a description of the moon would require many different concepts such as change of phase, day-night, change of visibility, and speckled-face-like appearance. Does the development of an invention such as the telescope add new concepts to our idea of "moon"?

Now, both Hales and Lavoisier (see Page 23 of the Case) describe the atmosphere. Both of them used many, many concepts in their descriptions. Their descriptions differ because some of the concepts on which they were based were not the same. It is interesting to consider which of their concepts about the atmosphere were the same , and which were different.

*** For further discussion and illustrations of how new concepts arise from experiments or observations, see CONANT, pages 104-105, 42, 54, 73-74. ***

PHYSICS

HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

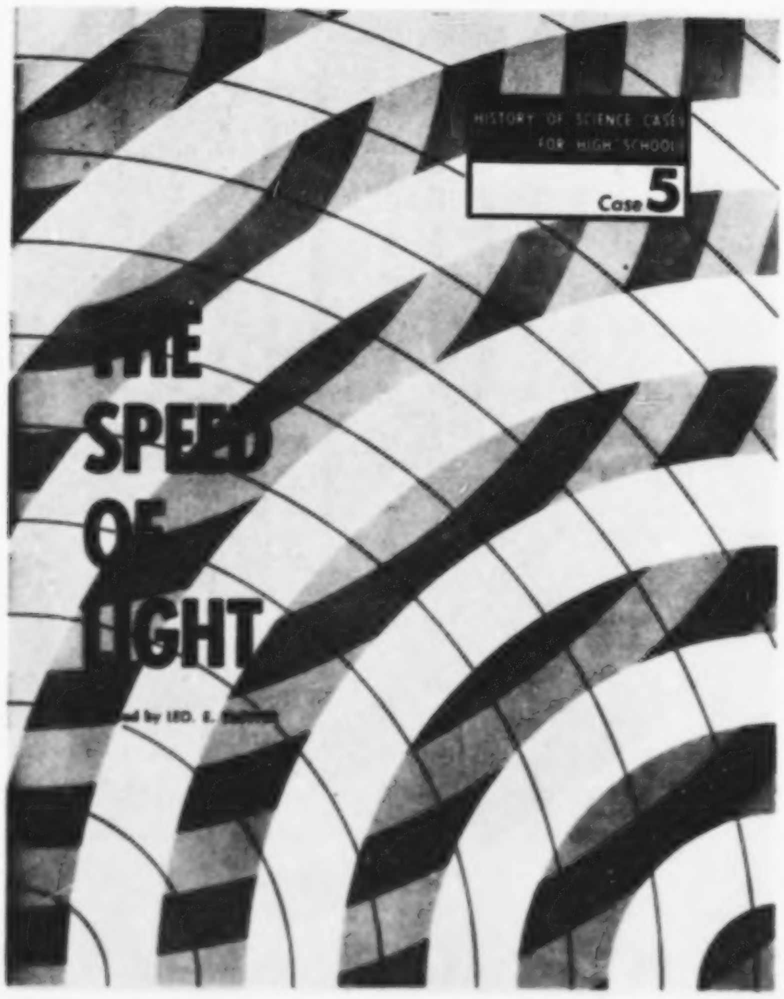
Case 4

Prepared by LEO. E. KLOPFER

FRAUNHOFER

A a B C D Eb F G H I

LINES



HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 5

THE SPEED OF LIGHT

Prepared by LEO. E. KLOPFER

HISTORY OF SCIENCE CASES FOR HIGH SCHOOLS

Case 6

AIR PRESSURE

Prepared by LEO. E. KLOPFER

TORRICELLI

Why might Fraunhofer have felt that an explanation of the FRAUNHOFER LINES was outside his area of competence? -- By the way, what do we mean by an "area of competence"?

Is it a good thing for an investigator to specialize in one rather narrow line of study?

How could other scientists find out about Fraunhofer's work?

To what extent can the direction that science will take be predicted?

Do you know of any everyday examples of flames colored by chemicals?

Why are chemists interested in quick tests for chemical elements? What is meant by "reliable"? Why is reliability important?

How do scientists obtain pure chemicals? -- What does this tell you about the dependence of science upon advances in manufacturing processes?

of his discovery was outside of his particular area of competence, for in the conclusion of his paper he remarked:

Why might he have felt this way?

> In all my experiments I could, owing to lack of time, pay attention to only those matters which appeared to have a bearing upon practical optics. I could either not touch other questions, or at most not follow them very far. Since the path thus traced in optical experiments seems to promise to lead to interesting results, it is greatly to be desired that skilled investigators should devote attention to it.

An investigator must select his line of study and put others aside. Is this a good thing?

Now, despite the fact that Fraunhofer's work was well-known to his contemporaries, an adequate explanation of the FRAUNHOFER LINES was not forthcoming for more than forty years. The eventual explanation of this phenomenon came about largely through new developments in an area of study which, at first sight, seems far removed from the appearance of dark lines in the spectra of the sun and other stars. The new developments were made in the investigation of the colored light of flames.

How could other scientists find out about Fraunhofer's work?

To what extent can the direction of science be predicted?

It had long been known that, when certain chemicals are put in a fire, the flames burn with characteristic bright colors. As the science of chemistry developed, a number of chemists began to use these characteristic colors as a quick means of testing for the presence of certain chemical elements. Such flame tests are still used today, as you probably know. (See exercise 7, page 25.) However, except for a few elements, the flame tests are not very reliable because the observations are difficult to reproduce, so that chemists sought for a more dependable means of rapid qualitative analysis.

Do you know any everyday examples of this?

Why are chemists interested in such quick tests?

What is meant by "reliable"?

It had occurred to a number of investigators to examine the colored flames by means of a prism. Again, the observations were confusing. Three difficulties were chiefly responsible for the confusion in the observations, viz., the chemicals available for experiment were not sufficiently pure; in the existing oil and alcohol burners, the burning

(It's a tough life!)

How do scientists obtain pure chemicals?

Pages from Case 4 - 'FRAUNHOFER LINES'

/P. 10, Q. 1/

Why might Fraunhofer have felt that an explanation of the FRAUNHOFER LINES was outside his area of competence?--By the way, what do we mean by an "area of competence"?

As an optician, his major work was in examination of the optical properties of various substances, rather than the properties and nature of light. Any attempt to explain the presence of dark lines in spectra would have involved Fraunhofer in theorization about the nature of light, a thing he felt unfit to do. It is a moot question whether he was in fact incompetent to carry through such a theorization. The chief point is how vital an individual's judgment is in setting tasks and limiting the range of his inquiry.

An "area of competence" is a vaguely-defined zone of likely success in judgment and analysis (if we are talking about intellectual competence, rather than mechanical or technical competence). It may be narrowly defined, so much so that generalizations are almost always avoided (Fraunhofer himself, and modern Russian science education both show this, with the former self-imposed limits and the latter socially-imposed). It may be widely defined, allowing free rein for generalizations (Newton or Einstein).

/P. 10, Q. 2/

Is it a good thing for an investigator to specialize in one rather narrow line of study?

This question is an extension of the previous one. There is no pat answer. Although Fraunhofer used his best judgment, presumably, in refraining from theorization, the net result was a delay of explanation for forty years. The overall dimensions of scientific research have expanded enormously, and the individual scientist tends to be working deeply within a fairly narrow area, but the dilemma of judgment is unchanged from Fraunhofer's time. Because of today's high specialization, the modern scientist does not have the opportunity to make broad generalizations about nature. Often, he does not have the option to make such generalizations even within his special field, because the research demanded is too strenuous or too expensive for his university to support. He may, with luck, find a small area of investigation, which provides him with enough theorizing and progression to new levels of experimentation to be rewarding personally and professionally. He may turn away from research, if frustrated by lack of funds or from being bored by routine activities. He may devote more attention to his own teaching, or to the improvement of science education in public schools, or he may succumb to the wiles of industry.

"Is it a good thing?" is difficult to say. Today, the nature of scientific research demands this degree of specialization to achieve overall success in new theory. Changing this nature seems impossible. If a scientist is to be creative as well as happy, he must adjust to the demands of the present situation.

/P. 10, Q. 3/

How could other scientists find out about Fraunhofer's work?

*** This is the first of two questions concerned with the means by which scientists communicate information and ideas. We shall return to the same theme in P. 16, Q. 5. ***

Some ways through which a scientist may learn about the work of his colleagues are:

1. published books
2. articles in journals
3. courses, lectures, and seminars
4. papers presented at meetings of scientific societies
5. informal talks with people he sees at meetihgs
6. personal correspondence with other scientists
7. asking someone who is more familiar with a given field than he is

In the present instance, other scientists probably learned of Fraunhofer's work through means 2, 4, 5, and 6 in the above list.

Fraunhofer published in the journal of the Akademie der Wissenschaften in 1817 and 1821 and in Gilbert's Annalen der Physik in 1823. These articles were in German. Although his work was followed up by David Brewster (1833), William Hallows Miller (1833), John Herschel (1840), and William Allen Miller (1845), we do not know whether they had read any of Fraunhofer's papers

*** At about this point in the study of the Case, we suggest that you try your students on an informal 15- or 20-minute written quiz. There might be two questions, one dealing with the physics subject-matter of the Case and the other with an idea about science or scientists which has been explored thus far. Two appropriate questions which we suggest are:

1. For each of the following men, tell [1] what he observed, [2] how he made his observations, and [3] what interpretation he gave to these observations:
    (a) Isaac Newton
    (b) William Hyde Wollaston
    (c) Joseph von Fraunhofer

2. Suppose that a bright General Science student has noticed you carrying the Case booklet, FRAUNHOFER LINES, around the school, and says to you:
    "Gee! Fraunhofer certainly must have been a great scientist
    to have those lines named after him."

    Keeping in mind some of the points about scientists and greatness mentioned in this Case, what would you say to this bright, young student?

***

Section Four. (Bunsen and Kirchhoff) :: Text— From Page 11, second paragraph to conclusion on Page 21.
Exercises 7 through 10.

*** This section is the heart of the entire Case. It is a complex section, for it introduces a new phenomenon (bright lines in spectra), includes the unexpected denouement of an hypothesis which links the Fraunhofer lines with these bright lines, and intimates that much further research has come from Kirchhoff's insight into absorption-emission spectra and the techniques for analysis which he and Bunsen worked out. ***

*** The most interesting aspect of the backgrounds of Bunsen and Kirchhoff is the coincidence of their interests and efforts on spectral analysis in 1859 at Heidelberg. One a chemist, the other a physicist; the first inclined toward technological problems, the second toward matters of phsical theory. Their joint research is an interesting fore-runner of much modern research, where individual scientists bring diversified backgrounds and interests jointly to bear on a project with results of value to science generally and with some implications for further research within the special interests of each individual. ***

*** This is a long section. To handle it within a reasonable period, we suggest that exercises 7 and 9 may be combined, with no loss of effectiveness. Also, the answering of the marginal questions should be spread out over two home assignments. — We give some Notes on Exercises (7 and 9), 8, and 10 in Part III of this guide. Exercise 10 is the crucial experiment of the Case; taking an entire period for the demonstration and discussion should ensure its success. — For your own reading, TAYLOR, pages 534-548, is very helpful for this section, as is the PEARSON-IHDE article. ***

/P. 10, Q. 4/

To what extent can the direction that science will take be predicted?

The direction of science - basic insights into and theories about the behavior of nature- cannot be precidted with any great confidence. By contrast, technological implications of new scientific concepts do yield to prediction, even though technological readiness may lag. (As an example of this, travel of satellites was a technological implication predictable on the basis of Newton's lawa of motion almost three hundred years ago, although the technology has only recently become available.) In trying to predict what direction science will take, the most the scientist can do is to list tentatively unsolved questions, of which there are always some apparent. Then, the process of experimentation with these factors in mind will evolve, perhaps answering some of the questions, certainly raising new ones.

The current research into nuclear particles typifies this well. Increasingly powerful energy sources used in attempts to determine the properties and nature of what, at first, seemed a small number of nuclear particles (the electron, proton, neutron) have succeeded in showing the existence of many unexpected particles, whose nature is still unclear. The scientific inquiry has shifted only in scale. Formerly nuclear physicists asked about the electron, protom, neutron; now they ask questions about the much larger ensemble. The hope still exists that some underlying and simplifying natural law will emerge, although

(continued on II-22)

/P. 10, Q. 4/ (continued)

admittedly the present state of nuclear research yields only increasing complexity and obsolescence of earlier concepts.

In the present instance, the new concept that would provide an explanation for the Fraunhofer Lines arose from an entirely unexpected quarter. It is doubtful that anyone could have told Fraunhofer that an understanding of the astronomical phenomenon he discovered would evolve from a study of colored flames by chemists. Similarly, no one today can predict the particular course of investigation that will lead to a resolution of the dilemma of the nuclear physicists.

*** The question of predicting the course of science is further discussed in P. 18, Q. 2. ***

/P. 10, Q. 5?

Do you know of any everyday examples of flames colored by chemicals?

Colored fireworks; chemically treated fireplace logs.

/P. 10, Q. 6/

Why are chemists interested in quick tests for chemical elements? What is meant by "reliable"? Why is reliability important?

The chemist starts with a chunk of unidentified matter. After he decomposes it via heat, water, acids, bases, etc., his task of identification is made easier if he has a speedy, reliable test which does not necessitate chemical combination and which produces a unique result. Flame tests per se are not reliable, unless a non-luminous flame is used in the burner and a spectroscope is used to uncover masking effects, due particularly to sodium.

Reliability is always a matter of degree. It means getting the same result time after time from the same substance, with no possibility that another substance is producing the effect.

*** If you wish to go into a further discussion of reliability, GOLDSTEIN, pages 179-182, provides a good guide. Especially useful is the last section, beginning near the bottom of page 181. ***

"Experiments and Exercises" from the HOSC Units

(In the Case booklets, space is provided for students to record observations and to answer questions.)

From Case 1 - THE SEXUALITY OF PLANTS.

1. Examination of Pollen Grains. ::: Collect pollen grains from several different plants. Mount the grains on a microscope slide in a drop of water or in melted glycerine jelly. Examine the mounted grains under the low power of the microscope. How do the pollen grains differ? Sketch some of the different shapes that you see. ... Estimate the relative size of the pollen grains, that is, how large are the pollen grains compared with the total size of the plant from which they come? ... Do you think it might be difficult to imagine how a huge tree could start from the minute grains of pollen? Might this be a factor in making the idea of sexuality of flowering plants "hard to take?"

6. Classification. ::: Collect a large number of different kinds of flowering plants. Try to get at least 30 different kinds. ... Now, classify your collection. What basis will you use for classification: color? size? odor? number of petals? shape? - See if you can work out a useful system that will include all the plants in your collection. What do we mean by "useful"? ... Do you see why the systematic botanists of the 17th century may have had difficulties in arranging their collections? ... (See Ex.7 on the Linnaean System.)

From Case 2 - FROGS AND BATTERIES.

5. Galvani's Second Series of Experiments. ::: This is the series of key experiments in which Galvani believed he had discovered animal electricity. You can do them easily yourself without any special apparatus.

   Prepare a frog as Galvani did (see illustration on page 25), and lay it on an iron plate (a sheet cut from a "tin can" will serve nicely). Touch one end of a short copper wire to the sciatic nerve of the frog and touch the other end to the iron plate. What do you observe? ... Substitute other metals for the copper wire. Substitute a glass rod, a strip of paper, a piece of wet string, your hand, etc. What happens each time?

   Now, place your frog on a glass plate, and try arcs consisting of pairs of different materials, both metals and non-metals. What materials must be in the arc for you to obtain contractions? Where does the electricity that is causing the muscular contractions come from?

   Form an arc of two dissimilar metals, say copper wire and iron wire or copper wire and a zinc strip. With the prepared frog on a glass plate, apply both ends of the arc to the sciatic nerve. Is there a contraction of the muscles? ... Similarly, apply both ends of an arc, consisting of two dissimilar metals, directly to the muscle. Does the muscle contract? ... What do these last two experiments show? If Galvani did some experiments similar to these, did he take account of them in his theory of muscular contraction?

7. An 11¢ Battery. ::: You can easily make a simple battery for 11¢ from two dissimilar metals, a penny (95% copper) and a dime (90% silver). Simply cut a piece of filter paper, dip it in salt solution, and place it between the penny and the dime. With two lengths of copper wire, connect the penny and the dime to the terminals of a galvanometer. Do you get a current from your 11¢ battery? ... Will your 11¢ battery produce a current with the penny and the dime in contact and the moistened filter paper on one side? ... Explain this effect.

From Case 9 - THE CELLS OF LIFE.

1.Hooke's Experiment. ::: Obtain a clean piece of cork, and, with a razor, cut as thin a slice as you can. Cut a piece of this thin section and place it on a microscope slide. Examine the cork under a tripod magnifier or under the low power of the microscope. Do you see the cells that are "not unlike a Honeycomb"?

Add a drop of water to the cork section on the slide, and cover it with a coverslip. Again observe under the low power of the microscope. Do you get a better view than you did the first time? Why? Make a drawing of what you see.

Cut a thin section of the pith from an elder tree or one of the rushes. Make a wet mount and observe under low power. Can you see the cells, as Hooke did? .. Can you see any more under the high power (which Hooke did not have)?

7.Animal Cells. ::: To appreciate the difficulty that Schwann faced, you will want to examine a variety of animal cells under the microscope. Prepared, stained slides are best for this, but you can make your own wet mounts of several different kinds of animal cells. Here is one suggestions:

Place a frog in a pan or jar containing 1 inch of water, and allow it to stand for about four hours. The water will become cloudy with thin flakes of the outer layer of skin. With a needle, lift out a small piece of this material and place it in a drop of water on a clean microscope slide. Try to straighten out the material into a thin sheet, and stain it with fountain-pen ink (or methylene blue). Put on a coverslip and observe under low power, then under high power. Can you see a cell wall, nucleus, cytoplasm? .. Make a labeled drawing.

Other convenient sources of animal cells are the lining of your mouth, a drop of frog's blood, or a drop of your own blood. For directions for making wet mounts of thesee, see, for example, Ella Thea Smith, Exploring Biology, 5th edition, pages 29, 30, 49. -- Make drawings of the animal cells that you observe (either in wet mounts or in prepared slides). In what ways are animal cells like plant cells? How are they different?

You should particularly look at a slide of animal cartilage cells. (This is the material which Schwann selected for his principal study.) Obtain a prepared slide of animal cartilage cells, and observe under low power, then high power. Can you see a cell wall, nucleus, cytoplasm? Make a a drawing of one of these cells. ... Is there a cell wall in this particular kind of animal cell? How was this important to Schwann?

From Case 3 - THE DISCOVERY OF BROMINE.

6.Balard's Preparation of Bromine. ::: Follow the directions in a laboratory manual for the standard preparation of bromine from potassium bromide, manganese dioxide, and sulfuric acid. Or, you may wish to follow Balard's directions, given in 1826 in his Memoir. Balard first obtained crystals of potassium bromide by treating an ether solution of bromine with potash and evaporating the liquid.

He says: "It is these cubic crystals that I successfully employ for the preparation of brome. I mix these crystals, after pulverizing them, with purified manganese dioxide, and upon this mixture, put into a small distilling apparatus, I pour sulfuric acid diluted with half its weight of water. This acid, if it were mixed with the /potassium bromide/ crystals alone, would extricate white vapours and very little brome, and the same effect is produced if the sulfuric acid in a more concentrated state be used with the mixture of salt and manganese dioxide, but employed as directed it produces orange vapours that condense into small drops of brome. These may be collected by immersing the end of the retort into the bottom of a small receiver filled with cold water. The brome which condenses in the neck of the retort precipitates to the bottom of the vessel on account of its great specific gravity." ((BE CAREFUL: bromine is POISONOUS!!!))

From Case 8 - THE CHEMISTRY OF FIXED AIR.

1. Preparation of Black's "Air". ::: Place a few grams of powdered white chalk (or powdered limestone) in the bottom of a glass tumbler. Slowly add dilute vitriolic (sulfuric) acid. What happens? ... Light a candle and place it on the table next to the tumbler. Protect from drafts. What properties of the "air" are demonstrated here? ... Hold a piece of burning paper in the "air" in the tumbler. Why is the flame extinguished?

11. Black's Comments on Lavoisier's Names. ::: The name "carbonic acid gas" to replace "fixed air" was only a small part of Lavoisier's new system of nomenclature. In his later lectures, Black made the following remarks about it:

"This philosopher [Lavoisier], therefore, associated several other eminent chemists in his labours, and the study soon acquired, in their hands, very great improvements. Assembled in Paris in 1787, and, confident of the superiority of what they called French Chemistry over all former doctrines and theories, they adopted a plan by which they hoped to give it universal currency and authority. They hoped to effect this by means of a nomenclature, so adapted to their system, that the very denominations of the different objects should imply the doctrines of their theories; so that, by using this language, it should scarcely be possible to think on chemical subjects in a way different from their theories."

What does black mean by his last remark? Is it a just evaluation? ... What was your personal experience in studying this Case? Did you find it hard to think of chemical problems in terms other than those to which you are accustomed? ... Does this mean that a scientist's investigations may be limited, in an unconscious way, by the terminology he adopts?

From Case 4 - FRAUNHOFER LINES.

3. On page 3 of our story, William Hyde Wollaston is called a "natural philosopher". What does this mean? Are scientists also philosophers?

In a short visit to the library, you can find out about some of Wollaston's numerous discoveries. Did Wollaston specialize in one scientific area, or did he have broad interests? Is this true of scientists today? What discoveries did he make? ... Would you call Wollaston a "great" scientist? Why or why not?

10. Kirchhoff's Experiment. ::: Kirchhoff allowed sunlight to fall on the slit of a spectroscope and matched up the two dark Fraunhofer D lines with the corresponding bright lines from a sodium flame. A simple set-up for repeating this experiment is described by Richard M. Sutton, Demonstration Experiments in Physics, page 414. A more convenient way of seeing the dark lines due to sodium (but without matching them with the Fraunhofer D lines) is given by W.C. Badock in The Science Masters' Book, Series II, Part I, page 162. The apparatus consists of a laboratory source of white light, a convex lens, a sodium flame, and another convex lens, all mounted in front of the collimator slit of a spectroscope or spectrometer. (By the way, what is the difference between a spectroscope and a spectrometer?)

The continuous spectrum is produced by a projection lamp (250-watt or more is recommended) with a rheostat or other form of dimmer in series. A 10-cm focus convex lens forms a real image of the filament in such a position that a sodium flame can be made to coincide with it. A similar lens focuses the combined light on the slit of the spectrometer. When the lamp is just glowing, the sodium lines will appear on a faint continuous background. (Compare this with Kirchhoff's first experiment on page 15.) As the brightness of the lamp is increased, this background varies, and the lines show up less and less, being indistinguishable at one point. Finally, the dark sodium lines are seen on a bright continuous spectrum. ... Can you see these effects?

From Case 5 - THE SPEED OF LIGHT.

9. Science is an international activity. We can realize this well when we look at the contributions that scientists from different countries have made to almost any field of investigation. Below are listed the names and nations of men who played a role in the measurement of the speed of light. The Roman numerals preceding the names indicate the century in which they did most of their work. -- Who were these men? What did they contribute to the measurement of the speed of light? What other contributions did they make to science and to society? --- Here are topics for some interesting reports to your class. A visit to the library will surely be helpful.

Denmark - XVII Ole Roemer
England - XVIII James Bradley XIX - Charles Wheatstone
France - XIX Dominique Francois Jean Arago, Armand Hippolyte Fizeau, Jean Bernard Léon Foucalt, Marie Alfred Cornu XX - Jean Mercier
Germany - XX A. Karolus, O. Mittelstädt, A. Hüttel
Italy - XVII Galileo Galilei
U.S. - XIX Simon Newcomb, Albert Abraham Michelson (also XX)
XX E.B. Rosa, N.E. Dorsey, F.C. Pease, F. Pearson, W.C. Anderson

Incidentally, isn't there something peculiar about the above list? Although there are representatives from six countries on the list, there are certainly many more countries than six in the world. Yet there are no scientists from these many other countries on the list. Why not? ... Can you suggest some reasons why one country may produce a considerable number of scientists at a given time while another does not? ... What does this mean to us today?

From Case 6 - AIR PRESSURE.

2. Galileo's Explanation of the Limitation of the Lift Pump. ::: Galileo explained 34-foot limit of the lift pump by suggesting that a column of water which was longer than this would break under its own weight. To see for yourself the analogy Galileo had in mind, you can use a string of bubble gum. Chew half a piece of bubble gum until it is soft, and then pull it out into a string at least four feet long. Hold the string of gum at one end and suspend it vertically. (You may have to stand on a chair.) Does the string of gum become longer? Does the length increase indefinitely? ... What caused the string of gum to become longer? What caused it to break? ... Is it possible that, by analogy, a similar situation occurs in a long column of water? But, is it always safe to reason by analogy?

8. Make Your Own Hydraulic Press! ::: In the hydraulic press, Pascal's Law is applied to a practical device. Pressure applied to a small piston is transmitted by the hydraulic fluid to a much larger piston. The operation of the hydraulic press is illustrated by the following model, which is easy to make.

Half fill a 500-ml beaker with water. Hold a length of glass tubing in the water and pour melted paraffin wax on the surface of the water to form a piston. When the wax is solidified, it forms a watertight piston. Attach a rubber tube to the glass tubing and fill it with water. Gently blow into the open end of the rubber tube. Considerable weight placed on the piston can be lifted in this way. ... Where is the small piston of this apparatus? How much pressure do you apply to it? (Make a rough estimate.) How much pressure is applied to the large (wax) piston? ... What is the approximate area of your small piston? What is the area of your large piston? What is the ideal mechanical advantage of your hydraulic press? ... Can you "blow up" your physics book with this apparatus?

(Do not write in this space)

UNIT TEST

Case 8

Your Name (print)________________ (Last) ________________ (First) ________ (MI) Date________________

School________________________________ Ccurse Title________________

Teacher's Name________________________ SCORE: ☐

DIRECTIONS:: There are four parts in this test. Answer all questions in each part and write your answers in this test booklet.

A perfect score on this test is 50 points. The number of points for each part is indicated in parentheses at the righthand margins.

PART I. (15)

1. The principal participants in THE CHEMISTRY OF FIXED AIR were: Joseph Black, Henry Cavendish, Stephen Hales, Antoine Lavoisier, Joseph Priestley. In front of each of the accomplishments listed below, write the last name of the man who was responsible for it. For any item in the list which was common knowledge to the men in the Case, print the letters "C.K."

a.)______________ Prepared "soda water".

b.)______________ Showed that quicklime could be produced by the roasting of limestone in lime-kilns.

c.)______________ Developed a technique for collecting water-soluble gases over mercury.

d.)______________ Explained chemically the behavior of limestone, quicklime, slaked lime, and lime water.

e.)______________ Perfected an apparatus for collecting gases so they may be studied.

f.)______________ Found that limestone is insoluble in water while quicklime reacts with water.

g.)______________ Explained burning as a combining with oxygen.

h.)______________ Determined the solubility and density of fixed air.

2. a.) What was the concept of atmospheric air befor the work of Joseph Black?

b.) What new idea of atmospheric air arose as a result of Black's work?

c.) Show how Black's work led to this new concept.

PART II. (12)

The selection below is adapted from an article in the December, 1959 issue of Scientific American. As you read the selection, look for phrases and words which tell something about the methods scientists use in their work, the organization of scientific activities, or the role of science and scientists today. Underline each such phrase you find and write in the margin at the right the aspect of science which that phrase illustrates.

You may not fully understand some of the facts presented in the article, but this is not important. What you should look for are illustrations of different aspects of science like those we discussed in the Case.

A sample has been done for you. Try to find AT LEAST SIX more items.

THE FLOW OF MATTER by Marcus Reiner

Everything flows, including solids such as concrete and steel. The exact way in which a material flows is of practical concern to the technologist and a difficult problem for the physicist.

Technologists are concerned with the means of making & doing useful things.

In 1868 the French physicist Henri Tresca demonstrated that very high pressures could force metallic lead to flow through tubes. From these experiments, Tresca's countryman, Barre de Saint-Venant, was able to develop a theory of the plastic flow of metals.

Here, until 40 years ago, matters rested. Physicists and engineers thought in terms of two types of material: fluids, which flow no matter how small a force is applied to them; and plastic solids, which flow only if the applied force exceeds a certain critical amount known as the yield stress. The classification was apparently clear-cut.

Then, in 1919, work on a problem in industrial chemistry upset this classical theory. E.C. Bingham of Lafayette College was investigating the properties of ordinary house paint. Consisting of pigments suspended in oil, paints were naturally considered to be fluids. A good paint should spread easily under the brush, and then flow enough to wipe out the brush marks. Also, a good paint, when brushed onto a vertical wall, must not run off under the force of its own weight before it dries. For the paint to stay put on the wall, it is not enough that it flow slowly; it must not flow at all. In other words, it must be a solid, according to the theory of Saint-Venant. To be sure, it is a solid with very low yield stress, so that the gentle pressure of the brush is enough to make it flow.

(continued on the next page)

PART II. (continued)

Bingham published his findings under the title,"Paint, a plastic Material and Not a Viscous Liquid". Surveying the classical ideas on flow, he found the theory quite inadequate to describe the behavior of substances like paint and the new plastics that the chemical industry was beginning to produce. He and his colleagues then set out to develop a modern theory.

At the same time, unaware of these developments in the U.S., I was working on the same problem in faraway Palestine. Over the next few years we became acquainted with one another's studies and a number of international meetings were held. A peculiar feature of the early meetings was that, although they were attended mostly by chemists, the subject matter would have been more interesting to physicists. Finally, in 1948, it was decided to set up a new society for the study of deformation and flow, which would attract workers from all the allied fields. It was named the Society of Rheology, after the Greek word for flow.

" " " " " " " " " " " " " " "

PART III. (10)

Statements 1.) and 2.) below contain ideas which were included in the Case you've just studied. Using each statement as a topic sentence, write a clear, well-organized paragraph to explain and expand the idea in the statement. Your paragraphs should each include an appropriate example taken from the Case to illustate the point.

1.) The introduction of a new scientific instrument or technique often makes possible a new line of investigation.

2.) A scientist's ideas and background influence the observations he makes and the interpretations he gives to his observations.

PART IV.

1. a.) Briefly describe the usual laboratory test for carbon dioxide.

b.) Explain what happens chemically in this test by:
(1) an equation based on Black's Theory of Lime

(2) a word equation using modern terminology

(3) a balanced equation using modern formulas

2. Suppose that you have a flask that you know contains a gas or a mixture of two gases. The contents of the flask are colorless and odorless. You also know that the flask contains either
(A) pure carbon dioxide
or (B) pure oxygen
or (C) pure hydrogen
or (D) a mixture of carbon dioxide and oxygen
or (E) a mixture of carbon dioxide and hydrogen

How could you find out what gas or gases are in the flask? (All the usual laboratory apparatus and chemicals are available to you, but do not try any procedure which might cause an explosion.) Be specific about each step.

(Continue on the back if necessary.)

Appendix B

Sample Forms Used in the HOSC Instruction Project

Some twenty different forms and more than fifty form letters, instructions, and information documents were prepared and used in the HOSC Instruction Project. Reproduction of all these items here would add considerable bulk to this report, but, we feel, would add little to its value. Thus, the sample of forms and instructions reproduced in this appendix is illustrative, rather than exhaustive. In addition to the four items given here, copies of the major portions of the three questionnaires used in the study have been reproduced in chapter III.

The following pages contain:

Reply Form - solicitation of participating teachers (form fe/1) Page 172 f.

Information and Instructions for Test Administrators (form i/6) 174 ff.

Instructions for Administration of TEST ON UNDERSTANDING SCIENCE (form i/7) 178

Report of Test Administration - TEST ON UNDERSTANDING SCIENCE (form fe/4) 179

HOSC Instruction Project

REPLY FORM

Name________________________________ ☐ Mr. ☐ Miss ☐ Mrs. ______

School____________________________________ ☐ Public ☐ Private

School Address________________________City____________State________

☐ YES.. I shall participate in the HOSC Instruction Project.
**Please be sure to read the paragraphs below
and complete the reverse side of this sheet.**

☐ NO.. I shall not be able to participate in the Project.
- ☐ Please send me further information about the HISTORY OF SCIENCE CASES when available.
- ☐ I have no further interest in this material.

* *

Since we do not wish you to commit yourself to participation in the HOSC Instruction Project without a full understanding of the exact nature of your commitment, we shall here spell out in some detail what participating teachers will be expected to do.

As each participating class will be randomly assigned either to the Experimental or to the Control Group, we can give no assurance at this time whether you will be asked to use the HOSC Instruction Method or not. However, you will be advised of your assignment by about June 15th, so that you may make suitable plans for the next school year.

Whether your Participating Class is in the Experimental or in the Control Group, you should allot class time for the Pre-Tests (2 periods) and the Post-Tests (2 periods), as scheduled on the Outline of the Project. You may also expect that there will be two or three questionnaires of moderate length to be completed. We shall, of course, try to make these questionnaires as concise as possible, so that they will take a minimum of your time to complete.

If your Participating Class is assigned to the Control Group, you will be asked to teach your class as you normally do. It is important that you DO NOT use the HOSC Instruction Method with this class during the 1960-61 school year, so that the evaluation data will not be confounded. You will be kept abreast of the progress of the Project through the year.

If your Participating Class is assigned to the Experimental Group, you will be asked to include two HOSC Instruction Method units in your teaching of this class between October 1, 1960 and February 15, 1961. Each unit will require approximately two weeks of classtime, and you may select any two of the three designed for the particular course you are teaching, either biology, chemistry, or physics. (Please refer to the enclosed sheet of Notes on the HOSC Instruction Method.) In teaching by the HOSC Instruction Method, it is especially important that you follow the suggestions given in the Teacher's Guide. These suggestions are in no sense restrictive, but they are intended to make possible some comparability of the evaluation data when the HOSC Instruction Method is used by many different teachers. ((Please note that, even though you may have more than one class section in the same subject, it will be possible to include only one of these sections as a Participating Class in the Project.))

((reverse side))

HOSC Instruction Project -- REPLY FORM for Participants : :

PARTICIPANT'S STATEMENT:::

I understand the nature of my commitment for participation in the HOSC Instruction Project. If my Participating Class is assigned to the Experimental Group, I agree to use the HOSC Instruction Method in accordance with the suggestions given in the accompanying Teacher's Guide.

____
(Signature)

PARTICIPATING CLASS:::

Subject______________________________Grade(s)______________

How, if at all, are students normally selected for this class?

( ) No selection. ( ) College-Preparatory Curriculum only.

( ) Non-College Curriculum. ( ) Other basis for selection:__________

Estimated Class Enrollment: Total _____ (Boys ______; Girls ______)

ADMINISTRATION APPROVAL:::

Has your school principal approved of your participation in the HOSC Instruction Project? ( ) Yes. ( ) No.

Remarks______________________________

Would it be desirable for us to write to your school principal to assist in obtaining his approval? ( ) Yes. ( ) No.

Principal's Name______________________________

We would like to write to your Superintendent of Schools to inform him of your participation in the HOSC Instruction Project. Is this agreeable to you?

( ) Yes. Superintendent's Name______________________________

( ) No. Address______________________________

YOUR COMMENTS and/or QUESTIONS:::

My home address is______________________________

Summer 1960 address, if different:______________________________

I shall be at this summer address from ____________ to ____________

fe/1:B

INFORMATION AND INSTRUCTIONS FOR TEST ADMINISTRATORS

You will be administering the Pre-Tests of the HOSC Instruction Project to the Participating Class, whose teacher and school are:

The top line of this label calls for an explanation --

The first three digits are the Class Code, in which
100, 200, 700, or 800 indicates a class in biology;
300 or 400 indicates a class in chemistry;
500 or 600 indicates a class in physics; and
900 indicates a "special" class.
The last two digits after the diagonal (/) are the Class Enrollment.

Your task as Test Administrator will consist of arranging a mutually-convenient time for giving the tests, administering the two Pre-Tests, mailing the answer sheets for both tests back to Cambridge, Mass. by 1st class mail; and returning the reusable and unused materials to Cambridge by parcel post. To assist you in carrying out this task, we have prepared these instructions and several standard letters and forms that should expedite the operation considerably.

1. Initial Contact with the Participating Teacher.

This is best done by mail. This mailing consists of a "Letter of Introduction" (1/12), an "Arrangements for Pre-Tests" form (fe/6), and a return-addressed envelope. If it is not already done, please type in your name and school in the blank line on the "Letter of Introduction", e.g., 'Mr. Richard S. Johnson of Ohio State University'. Complete the upper half of the "Arrangements for Pre-Tests" form, giving as wide a choice of alternate dates as is convenient for you. Unless it is already done, address the long white envelope to yourself. -- The participating teacher is waiting to be contacted and you should receive a quick reply.

2. Confirming the Test Date.

When you have received the teacher's reply, complete the "Confirmation of Pre-Test Date" letter (1/13) and mail it to the teacher. If you judge that this letter will not arrive at least two days before the Pre-Test date, make the confirmation by telephone. (Please be sure to include the cost of any toll calls on your expense voucher.)

AT THE SAME TIME, fill in the two blanks at the foot of the "Letter to the Principal" (1/14) and mail this also. -- We hope that this letter will assure you of a warm reception when you arrive at the school.

3. Concerning problems that may arise in arranging the test date.

Since the administration of both Pre-Tests will require approximately two class periods, there may be some difficulties in arranging the test date in certain schools. In this event, it will be necessary for you to apply your own best judgment as to how to resolve the situation. However, the following guide lines should be of value:

(A) The most advantageous arrangement is for you to administer both Test I and Test II on the same day. If only one period is scheduled for science on those days when you are able to go to the school, it may be possible to use part of a study period or an activity period to complete the testing. We have found that schools are frequently willing to co-operate in this way.

(B) If it is impossible to do (A), the next best choice is for you to administer Test I on the date that is arranged and to ask the participating teacher to give Test II on the following day or as soon thereafter as possible. The teacher would then take the responsibility for mailing the answer sheets of both tests to Cambridge. He should also see to it that the test booklets for Test II are returned.

(C) If you have the time to devote and if (B) does not seem to be a good possibility, the last alternative is for you to administer Test I on one day and to return to the school to administer Test II on a succeeding day. We know that this alternative represents a great imposition on your time and we hope that it will not be necessary to adopt it. Nevertheless, we are anxious to have the Pre-Tests competently administered.

Should your initial mailing to the teacher fail to receive a response within a reasonable time, please use whatever means are appropriate to contact the teacher to arrange a test date. (Include any additional postage or telephone charges incurred on your expense voucher.) The same suggestion applies if the exchange of the "Arrangements for Pre-Tests" form does not result in a mutually-agreeable test date.

4. Suggestions for the Test Day.

Test booklets, answer sheets, and electrographic pencils in the number equal to the Class Enrollment (plus a few extra) are supplied in the materials sent to you. (If you are administering the Pre-Tests to more than one class, the same test booklets are intended to be reused.) If it has not already been done, the pencils should be sharpened before setting out for the school.

When you arrive at the school, it is good practice (and, in most schools, mandatory) to announce yourself at the office. Stopping in at the school office will surely get you help in finding the right classroom; failing to stop may be disastrous.

INFORMATION AND INSTRUCTIONS FOR TEST ADMINISTRATORS - 3

5. Instructions for Administering Test I.

The first test to be given in all instances is the TEST ON UNDERSTANDING SCIENCE (TOUS). Instructions for administration of TOUS are contained on an attached sheet (green printing).

IT IS IMPORTANT THAT THE PARTICIPATING TEACHER DOES NOT LOOK AT TOUS!!! This test is the criterion instrument in the HOSC Instruction Project. The entire evaluation may be biased if the teacher has a chance to study this test. You may wish to explain this to the teacher, but, whether you do or do not, DO NOT LET HIM LOOK AT TOUS!

6. Instructions for Administering Test II.

The second test to be given in all instances is the OTIS MENTAL ABILITY TEST, Form Am. Instructions for administeration of the OTIS are contained on an attached sheet (red printing). If you do not administer this test yourself (--see section 3 above--), please pass these instructions on to the participating teacher.

7. Concerning students who are absent on the testing day.

We would like to have Pre-Test scores on TOUS and on the OTIS for all the students who are participating in the HOSC Instruction Project, both in experimental and in contfol groups. Unfortunately, this is not an ideal world, and some students will inevitably be absent on the day you do the testing. Hence, a dilemma arises as to what to do about these absentees. On the one hand, if a sizable proportion of the class does not take the Pre-Tests, all succeeding measures taken on that class will be very difficult to interpret. On the other hand, it is too much of an imposition on your time (and, incidentally, too great an expense for the budget of our Project) to have you return to the school to administer the Pre-Tests to a few students who happen to be absent on the testing day. The problem is complicated by the condition that we cannot allow the participating teacher to look too closely at TOUS.

Again, we shall rely on your own good judgment in reaching a decision on the question of what to do about absentees. We offer the following guide lines to assist you in reaching this decision:

(A) If about 70% or more of the students normally enrolled in the Participating Class are present when you administor Test I (TOUS), it will be best to forego administering the Pre-Tests to the few students who are absent. The over-all evaluation of the Project will not be seriously affected if only a few students miss the Pre-Tests.

(B) An exception to the general rule given in (A) may arise in case you are obligated to return to the school yourself for a second day of testing. (This is the distasteful alternative C of section 3 above.) In this situation, if any of the first day's absentees are present on the second testing day, you should give Test I (TOUS) to these students while the class as a whole is taking Test II (OTIS). The participating teacher should then administer Test II to these first day's absentees who do not take it at the same time that the class does. The participating teacher should also administer Test II to any student who took Test I but was absent when Test II was given to the class.

(C) If substantially more than 30% of the students normally enrolled in the Participating Class are absent when you administer Test I, the data subsequently obtained from this class will be of doubtful value for the evaluative analysis of the Project. Should this unfortunate eventuality occur and if you can afford to devote your time, we should like to ask you to make arrangements to return to the school to administer the Pre-Tests, or at least Test I, to the absentees. (Please include all additional costs of the second administration to the absentees on your expense voucher.)

(D) If you administer only Test I and the participating teacher administers Test II (--This is alternative B of section 3 above.--), please impress upon the teacher the importance of obtaining a score on Test II (OTIS) for every student who took Test I (TOUS). The reason for this is that, in our analysis, we shall be making a covariance adjustment of the TOUS scores on the basis of the OTIS IQ scores.

8. Mailing of the Answer Sheets.

A large, addressed manila envelope is included in your folder of materials for mailing the answer sheets used in the Pre-Tests back to Cambridge, Mass. Sufficient first class postage has been affixed to cover the answer sheets of the entire class for both Test I and Test II. As soon as both sets of answer sheets have been completed, convey the envelope to the sturdy hands of the Post Office Department, so that we can begin our data processing with the least possible delay. Please enclose both "Report of Test Administration" forms with the answer sheets. (The participating teacher may do this mailing in the event you do not administer both Pre-Tests to all the students yourself, as discussed in sections 3 and 7 above.)

9. Returning Materials to Cambridge.

When you have completed your administration of the Pre-Tests, please return all test booklets and pencils and any unused answer sheets to Cambridge by parcel post. An addressed label is included for this purpose. The rate for "Educational Materials" is 9¢ for the first pound and 5¢ for each additional pound.

10. Expense Voucher.

You should not omit finding an "Expense Voucher" (fe/7) in your folder of materials. The completion of this voucher is self-explanatory. If you administer the Pre-Tests to more than one Participating Class, please submit a separate voucher for each class. The small, return-addressed envelope is intended for the submission of your expense voucher. We shall see to it that a check is sent to you as quickly as we can get it processed through the mammoth machinery at this institution.

Instructions for Administration of
- TEST ON UNDERSTANDING SCIENCE
(Form X)

This form of the TEST ON UNDERSTANDING SCIENCE is designed for machine scoring. Pupils are not to make any marks on the test booklets. There are 60 questions in the test. The working time is 40 minutes. It is important to follow the exact procedure outlined below.

1. Distribute answer sheets and electrographic pencils.
   Have the students fill in the three lines at the side of the answer sheet. They should not write in the spaces intended for inserting the test scores.

2. Distribute test booklets and read directions.
   SAY . . . "Do not open the test booklets until you are told to do so. Please turn the booklet over to the back cover and read the directions, as I read them aloud."

   --- (Although high school students are undoubtedly familiar with taking a test in this format, the directions are to be read aloud because they contain the definition of "scientist" that is used in the test. This is found in the example which is explained in the middle of the page.) ---

   ALSO SAY..."There are 60 questions on this test, and you will be allowed 40 minutes to complete it. You will have to work rapidly, but do not rush. - - Are there any questions? I cannot answer any questions after you begin working on the test."

   --- (The most common question students ask is, "Shall I guess?"
   Answer: "There is no deduction for wrong answers. If you are not sure about the answer to a question, make the most careful guess you can.")---

   After questions, SAY ..."Open your test booklets to page 3 and begin working. Keep working until I tell you to stop. Be sure that you mark your answers in the proper spaces on the answer sheet. Make only one mark for each question."

3. Write on the board the exact time when students begin working on the test. Also write on the board the time when students must stop work.

   After exactly 40 minutes, SAY . . ."Stop! Lay your pencils down."

4. Collect the answer sheets, then the test booklets and pencils.

Please complete the "Report of Test Administration" form and submit it together with the set of answer sheets.

(Note: At the Pre-Test administration of TOUS, it is essential that the teacher of the Participating Class does not look at the test booklet.)

1/7

Report of Test Administration

- - - - - - - - - - - - - - - - - - - -TEST ON UNDERSTANDING SCIENCE
(Form X)

Class Code: ________ Answer Sheet Numbers:

Date: ____________ ______ to ________

Administered by: ____________ ______ to ________

______ to ________

Time started working: ________

Time finished: ______

Net time students worked on the test: _____ minutes (40 minutes are allowed.)

Was this working time adequate for students to finish the test?

( ) Too short -- many did not finish.
( ) Just about right.
( ) Too long -- most had more time than they needed.

Note here any irregularities (student starting late, student leaving test, fire drill, etc.) and give student names ---

How many students enrolled in the class did not take the test? __________
Their names are ---

Please indicate your own comments concerning the TEST ON UNDERSTANDING SCIENCE and any general student reactions ----

fe/4

Appendix C

Acknowledgements

The successful operation of the HOSC Instruction Project was made possible through the cooperation and help of many people and organizations. We wish to thank especially the participating teachers for their efforts. The names of the participating teachers, with their schools, science subjects, and code numbers assigned to their classes, are listed on page 182 to 188. We are also most grateful to our Regional Advisers (page 189) and to the Test Administrators (pages 190-191) for the fine manner in which they executed their tasks. In addition, we are happy to make the following acknowledgements:

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To all these persons and organizations, we wish to record our indebtedness and to express our sincere thanks.

PARTICIPATING TEACHERS

Alabama

Mrs. Mildred M. Hardy, George Washington High School, Montgomery
(Chemistry - Control - 453)
Mr. E. Leland Watkins, Indian Springs School, Helena
(Chemistry - Experimental - 359)

California

Mr. Louis Alcorta and Mr. Norman Keeve, Galileo High School, San Francisco (Biology, team teaching - Experimental - "B"-991)
Miss Ann J. Ahokas, Mission High School, San Francisco
(Chemistry - Control - 493)
Mr. Ray Bergman, Galileo High School, San Francisco
(Physics - Experimental - 693)
Mr. Robert A. Brandberry, Balboa High School, San Francisco
(Biology - Experimental - 195)
Sister M. Clarice, O.P., Immaculate Conception Academy, San Francisco
(Chemistry - Control - 499)
Mr. J. Bruce Duncan, Pacific High School, San Leandro
(Chemistry - Control - 492)
Miss Lola Eriksen, San Carlos High School, San Carlos
(Biology - Experimental - 194)
Mr. John S. Harlan, Polytechnic High School, San Francisco
(Physics - Experimental - 591)
Mr. Lawrence E. Hatch, Sequoia High School, Redwood City
(Biology Experimental - 193)
Mr. Albert C. Heppe, Sonoma High School, Sonoma
(Physics - Control - 691)
Mr. Carl R. Koenig, Jr., Lowell High School, San Francisco
(Physics - Control - 692)
Mr. Robert Lew and Mr. Herbert McCall, Galileo High School, San Francisco (Chemistry, team teaching - Experimental - "B"-992)
Mr. Robert W. Nordstrom, Hoover High School, San Diego
(Chemistry - Experimental - 391)
Mr. Robert Tellefsen, Napa Senior High School, Napa
(Chemistry - Control - 491)

Connecticut

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(Chemistry - Experimental - 311)
Mr. A. Henry Grabber, RHAM High School, Hebron
(Biology - Experimental - 711)
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(Physics - Control - 619)

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Connecticut (Continued)

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(Chemistry - Control - 412)
Mr. Richard Salinger, Wilton Junio-Senior High School, Wilton
(Physics - Experimental - 513)

Florida

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(Biology - Control -251)
Mr. Charlie P. Cowen, Bradford High School, Starke
(Chemistry - Experimental - 351)
Mr. Bernard E. Kane, Jr., Deland High School, Deland
(Chemistry - Control - 451)
Mr. William Konegay, Florida A. & M. University High School, Tallahasee (Biology - Experimental - 151)
Miss Janet Whitman, Sarasota High School, Sarasota
(Lab-Preparatory - Experimental "B"- 951)
Mr. John D. Woolever, Riverview Junior-Senior High School, Sarasota
(Biology - Experimental - 152)

Georgia

Mr. C. W. Whitaker, Jr., South Fulton High School, East Point
(Biology - Control - 253)

Hawaii

Mr. Will Kyselka, University High School, Honolulu
(Chemistry - Experimental - 392)

Illinois

Sister M. Johannita, St. Gregory High School, Chicago
(Physics - Control - 669)

Indiana

Miss Marguerite Murphy, Washington High School, South Bend
(Chemistry - Experimental - 364)
Mr. William W. Strow, Culver Military Academy, Culver
(Chemistry - Experimental - 368)

PARTICIPATING TEACHERS (Continued)

Iowa

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Sister Mary Marjorie, O.S.F., Wahlert High School, Dubuque (Chemistry - Experimental - 388)

Kansas

Mrs. Norma E. Auernheimer, Ellinwood Rural High, Ellinwood (Chemistry - Control - 482)

Kentucky

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Maine

Mr. Lawrence J. Griffin, Orono High School, Orono (Chemistry - Control - 413)

Maryland

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Miss Susan E. Boyer, Montgomery Blair High School, Silver Springs (Biology - Control - 235)

Mr. Jastrew M. Levin, Baltimore Polytechnic Institute, Baltimore (Chemistry - Experimental - 333)

Sister Regina, S.N.D., Maryvale-Trinity College Preparatory, Brooklandville (Biology - Control - 239)

Massachusetts

Mr. Robert E. Bertram, Salem Classical and High, Salem (Biology - Experimental - 111)

Mr. James Dadoly, Acton-Boxborough Regional High School, West Acton (Biology - Control - 811)

Mr. Norman H. Fredette, Oakmont Regional Junior-Senior High School, South. Ashburnham (Chemistry - Control - 411)

Mr. Philip E. Kendrick, Beverly High School, Beverly (Biology - Control - 211)

Mr. Manuel E. Martins, Gloucester High School, Gloucester (Physics - Experimental - 511)

Mr. Frank A. Ruberto, Revere High School, Revere (Physics - Experimental - 512)

PARTICIPATING TEACHERS (Continued)

Massachusetts (Continued)

Mr. James Sullivan, Acton-Boxborough Regional High School,
West Acton (Physics - Control - 611)
Miss Katherine R. Townsend, North Quincy High School, North Quincy
(Biology - Control - 212)
Mr. Richard H. Whitney, Roxbury Latin School, West Roxbury
(Physics - Experimental - 519)

Michigan

Mrs. Margaret Anderson, West Intermediate, Jackson
(Biology - Experimental - 762)
Mr. John E. Arnett, J. W. Sexton High School, Lansing
(Chemistry - Control - 362)
Mr. Edward M. Brigham, Flint Central High School, Flint
(Biology - Experimental - 162)
Miss Katherine A. Hemmer, Walter French Junior High School, Lansing
(Biology - Control - 862)
Mr. William F. Humphrey, C. W. Otto Junior High School, Lansing
(Biology - Experimental - 763)
Miss Virginia Lewis, Southwestern High School, Flint
(Chemistry - Control - 463)
Mr. David R. McCall, Northern High School, Flint
(Chemistry - Control - 462)
Mr. Grayson Newark, Jackson High School, Jackson
(Chemistry - Control - 461)
Mr. Sidney M. Quigley, Redford Union High School, Detroit
(Physics - Control - 662)

Minnesota

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(Physics - Experimental - 581)
Mr. William R. Jepson, Edina Morningside High School, Edina
(Physics - Experimental - 582)
Mr. Lowell M. Johnson, Robbinsdale Senior High School, Robbinsdale
(Chemistry - Control - 481)
Mr. Thomas J. Pacholl, Washington High School, St. Paul
(Biology - Experimental - 181)
Mr. Oriville G. Ruud, Bloomington High School, Bloomington
(Physics - Experimental - 583)
Mr. Martin Thames, Minnetonka High School, Excelsior
(Chemistry - Experimental - 381)

Missouri

Mrs. June Fender, Willard High School, Willard
(Biology - Control - 282)
Sister John Mary, D.C., St. Vincent High School, Perryville
(Physical Science - Experimental - "B" - 989)

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Mr. Don. L. Bean, Grand Island Senior High School, Grand Island (Biology - Experimental - 184)

Mrs. Mary A. Coddock, Blair High School, Blair (Biology - Experimental - 182)

Mr. Glenn H. Crumb, University High School, Lincoln (Physics - Control - 683)

Mr. Lloyd L. Darrow, Benson High School, Omaha (Biology - Control - 281)

Mr. Ellis H. Jeffery, Lincoln Northeast High School, Lincoln (Physics - Control - 682)

Mr. Harley J. Hardison, Westside High School, Omaha (Biology - Experimental - 183)

Sister Mary Realino, B.V.M., Pius X High School, Lincoln (Physics - Experimental - 589)

New Jersey

Mr. Stephen Cepreghy, Jonathan Dayton Regional High School, Springfield (Physics - Control - 631)

Miss Grace Dick, Southern Regional High School, Manahawkin (Biology - Control - 231)

Miss Mary C. Dilinski, Ramapo Regional High School, Franklin Lakes (Biology - Experimental - 131)

Miss Lucy Hurley, Kearny High School, Kearny (Chemistry - Control - 431)

Mr. Authur P. Madsen, Senior High School, Teaneck (Physics - Experimental - 531)

Mr. Emil J. Piel, East Orange High School, East Orange (Physics - Experimental - 532)

New York

Mr. Louis W. Bixby, Weedsport Central High School, Weedsport (Physics - Experimental - 533)

Dr. Sol Charney, New Rochelle High School, New Rochelle (Natural Science - Experimental - "B"-931)

Mr. Leon Dorfman, Martin Van Buren High School, Queens Village (Biology - Experimental - 132)

Mrs. Gabrielle I. Edward, Abraham Lincoln High School, Brooklyn (Biology - Control - 232)

Mr. Harold Ewen, Plainedge High School, N. Massapequa (Biology - Control - 233)

Mr. Thomas V. Gillman, Huntington High School, Huntington (Chemistry - Experimental - 331)

Mr. Joseph Heymont, Yeshiva of Flatbush High School, Brooklyn (Biology - Control - 238)

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Mr. Samuel Ronsheim, Benjamin Franklin High School, Rochester
(Chemistry - Experimental - 334)
Mr. Stanley W. Starr, Ossining Junior-Senior High School, Ossining
(Chemistry - Control - 433)
Mr. Andrew J. Tivnan Sayville High School, Sayville
(Chemistry - Experimental - 332)

Ohio

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Mr. Robert H. Brown, Grove City High School, Grove City
(Biology - Experimental - 761)
Mr. Daniel Lee Dindal, Worthington High School, Worthington
(Biology - Control - 262)
Mr. Duane Ferris, Grand Valley High School, Orwell
(Chemistry - Experimental - 363)
Brother Charles Gausling, S.M., St. Joseph High School, Cleveland
(Chemistry - Experimental - 369)
Mr. James C. Grothaus, North High School, Columbus
(Physics - Experimental - 561)
Mr. James P. Hidy, Central High School, Columbus
(Biology - Experimental - 161)
Mr. Richard W. Hollstein, Montpelier High School, Montpelier
(Biology - Control 263)
Mr. Charles S. Kreider, Wadsworth Senior High School, Wadsworth
(Chemistry - Control - 464)
Mr. James F. Lambourne, Upper Arlington High School, Columbus
(Biology - Control - 261)
Mr. Robert H. McBurney, Worthington High School, Worthington
(Chemistry - Experimental - 361)
Mr. Robert C. McCafferty, Litchfield Junior High School, Akron
(Biology - Experimental - 764)
Mr. Gerald F. Ocock, West High School, Columbus
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Mr. Irwin L. Slesnick, University School, Columbus
(Science II - Experimental "B"-969)

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Mr. Paul M. Zorn, Jr., William Tennent High School, Johnsville
(Physics - Control - 632)

Vermont

Mr. Irwin H. Hoxie, Danville High School, Danville
(Chemistry - Experimental - 312)

Virginia

Miss Virginia C. Ellett, Thomas Jefferson High School, Richmond
(Chemistry - Control - 452)
Mr. Morris S. Tischler, Fairfax High School, Fairfax
(Chemistry - Experimental - 352)

Washington

Mrs. Mary R. Ames, Ballard High School, Seattle
(Biology - Control - 291)
Mr. Raymond A. Wohlrabe, West Seattle High School, Seattle
(Chemistry - Control - 494)

Wisconsin

Mr. Erlend Johnson, South High School, Sheboygan
(Physics - Experimental - 562)

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Dr. Robert Stollberg
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San Francisco State College
San Francisco, California

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Jagdish Goyal, Iowa State Teachers College, Cedar Falls, Iowa	i
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Rodney A. Lane, Florida State University, Tallahassee, Fla.	i
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Dr. R. W. Martin, Southwest Missouri State Coll. Springfield, Mo.	i
William May, S.F. State College, San Francisco, Calif.	f
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David G. Miles, Montclair State College, Montclair, N. J.	i
James W. Miller, Harvard University, Cambridge, Mass.	f
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Prof. Robert K. Wickware, Willimantic State Coll., Willimantic Connecticut	i
Bernhardt Wohlgemuth, S. F. State Coll., San Francisco, Calif.	i

i = administered pre-tests
f = administered post-test